BBC

TAKE A GRAND TOUR OF AUTUMN'S NIGHT SKY

Discover the highlights of the new dark-sky season

#197 OCTOBER 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

STARGAZING IN THE CITY

How to cut through the glare and make the best of light-polluted skies

SEARCH FOR A SINGULARITY

Can you observe the giant star circling a black hole?

Astronomy Photographer of the Year

SEE THE WINNING IMAGES INSIDE!

HUBBLE OUT OF TROUBLE

The inside story of bringing the venerable space telescope back to life

ASTEROID EXTINCTION

Origin of the dino-killing meteor discovered

STUNNING STRUCTURES

The beauty of planetary nebulae explained

LUCY IN THE SKY

Mission to orbit Trojan asteroids set for launch

Welcome

There's more to observe in city skies than you might think

As the evenings draw in and astronomers everywhere feel a sense of anticipation at real darkness returning to the skies, this issue we're taking a look at stargazing from towns and cities – where many of us live. Will Gater is your guide to getting the best observing time from these more brightly lit locations, sharing expert tips for observers with the naked eye, telescopes and binoculars, as well as advice on imaging targets. Discover the best sights to seek out on **page 36**.

If you are an urban astronomer, there's plenty of advice there which will also be handy for our Grand Tour of highlights in autumn's night skies. Starting on **page 60**, Stuart Atkinson takes us from one seasonal sight to another in an observing expedition that's ideal for newcomers and experienced amateur astronomers alike, in celebration of the return of dark skies.

However, when darkness fell on the Hubble Space Telescope and it abruptly shut down in June, the news wasn't so welcome. Was this latest glitch in the orbiting observatory's long and venerable history to be the last? Happily it was not to be, and on **page 66** Melissa Brobby tells the inside story of how the mission team at Goddard Space Flight Center found and solved the issue, restoring Hubble once again to providing a stream of scientific data and amazing images.

And speaking of stunning space imagery, look no further than **page 28**, and the winning photographs from the 13th Astronomy Photographer of the Year competition. They are a breathtaking collection of astrophotos, representing the pinnacle of imaging skill and dedication – I'm sure you'll join me in congratulating the winners.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 21 October.

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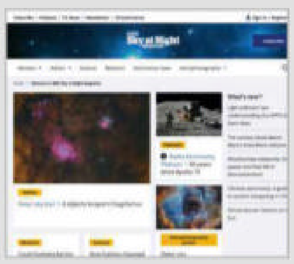
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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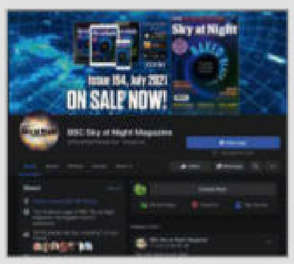

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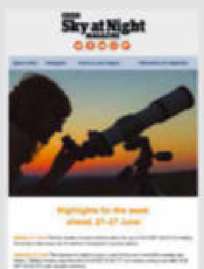

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

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Ⓒ = on the cover

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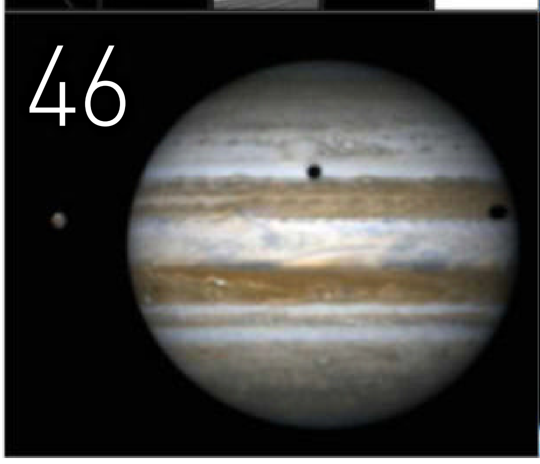
New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Melissa Brobby

Amateur astronomer

"When Hubble went out of action this summer it was a nerve-wracking moment, so it was great to be able to look at the work NASA put in to bring it back online." **Melissa finds out how Hubble was repaired, page 66**

Will Gater

Astronomy journalist

"While light pollution is a clear threat to our night skies, I wanted to show that there are still ways to get into astronomy and things to see from brightly-lit towns and cities." **Will offers tips for observing under city-lit skies, page 36**

Penny Wozniakiewicz

Planetary scientist

"It was great to write about the upcoming analysis of samples from asteroid Ryugu and to show that sample return is just the beginning of the story!" **Penny finds out how scientists analyse space rocks, page 72**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/P28YQYE/** to access this month's selection of exclusive Bonus Content

OCTOBER HIGHLIGHTS

Exclusive interview: Tim Peake

The UK's first ESA astronaut talks writing sci-fi, life on the ISS and the prospect of humans landing on Mars.

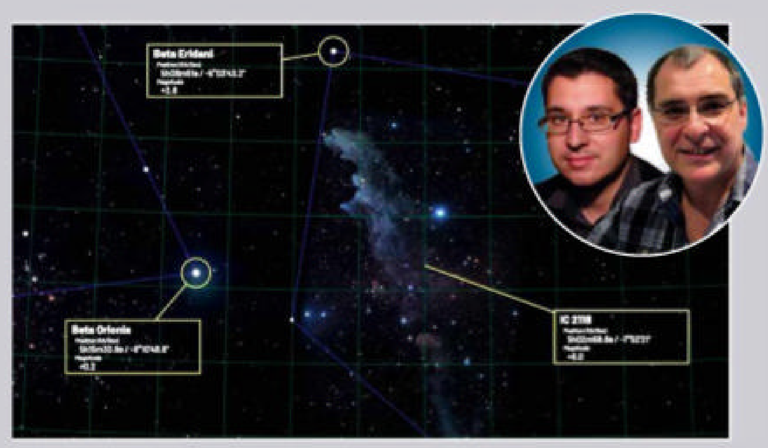
Watch *The Sky at Night: Exploring Jupiter*

Maggie and Chris find out what NASA's Juno mission has discovered at Jupiter and speak to some of the UK mission scientists.

APY 13: see all of this year's winners

See the winning, runner-up and highly commended entries from the 2021 Astronomy Photographer of the Year competition.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

LORD OF THE RINGS

A newly released image shows the 'light echoes' from a briefly reignited black hole

CHANDRA X-RAY OBSERVATORY/PAN-STARRS/NEIL GEHRELS SWIFT OBSERVATORY, 5 AUGUST 2021

V404 Cygni became a short-lived celestial celebrity in 2015 when NASA's Neil Gehrels Swift Observatory, a space observatory dedicated to scrutinising gamma-ray bursts, detected an unusual burst of X-rays coming from the constellation of Cygnus, the Swan.

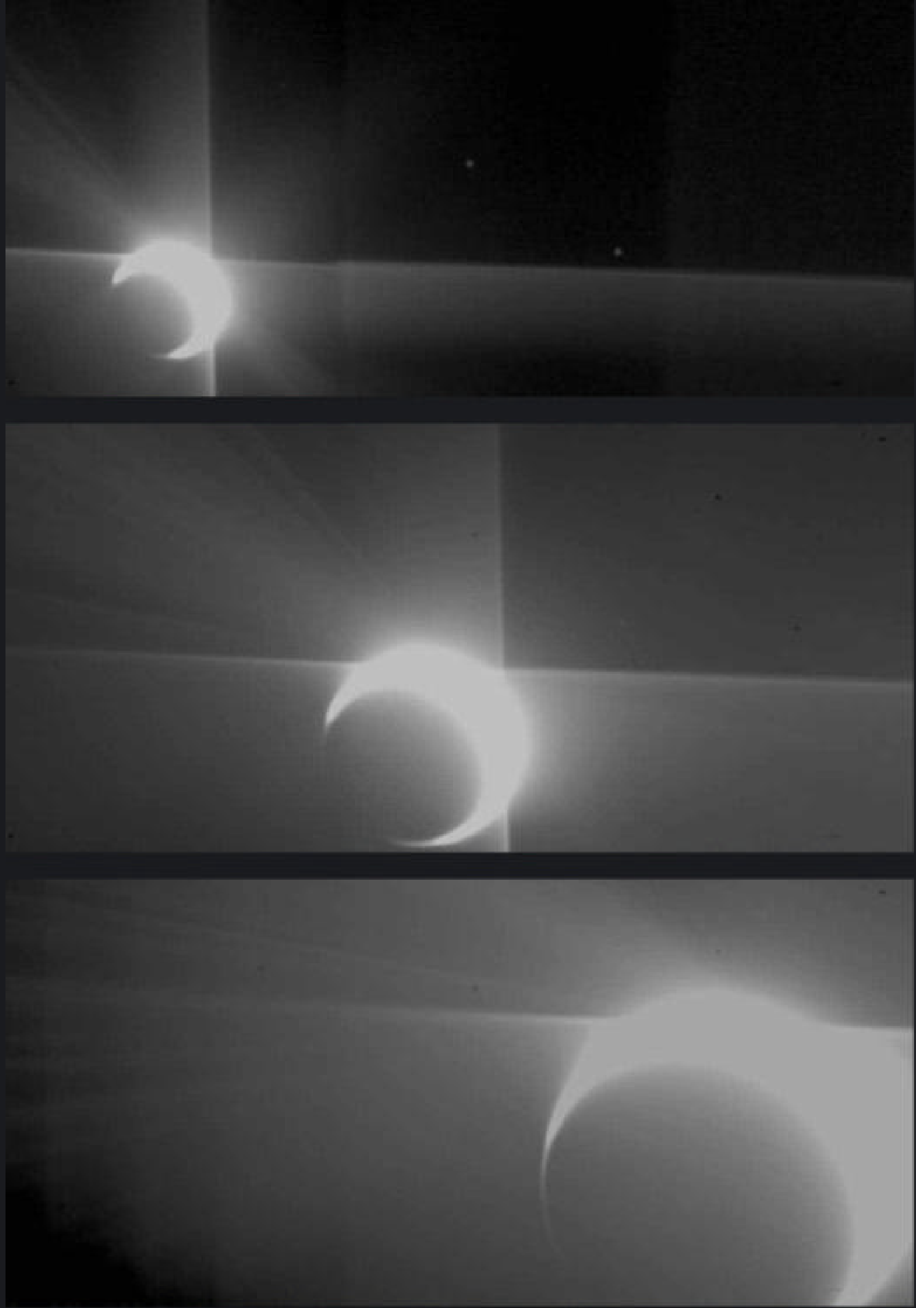
The source was a black hole 7,800 lightyears away, waking up from its slumber. Suddenly the binary system became the focus of observatories worldwide as they watched it flare and sputter back to life after two decades in repose.

The high-intensity X-rays streaming out were the result of the black hole dragging material away from its companion star, then releasing jets of gas that formed a disc. As that heated to a million degrees V404 became an X-ray source 50 times brighter than the Crab Nebula, M1.

In this newly released image from the Chandra X-Ray Observatory we see the 'light echoes' created as those rays bounced off dust clouds around the black hole. The different apparent sizes of the concentric rings reveal their relative distances; rings appear larger if the cloud is closer to us, and vice versa.

MORE **ONLINE**
A gallery of these and more stunning space images

X-RAY: NASA/CXC/U.WISC-MADISON/S. HEINZ ET AL.; OPTICAL/IR: PAN-STARRS



△ Hello Venus

SOLAR ORBITER, 7–9 AUGUST 2021

These stills are taken from footage captured by the Heliospheric Imager aboard ESA/NASA's Solar Orbiter as it sailed within 7,995km of Venus. The planet (looking like a crescent) approaches from the left while the Sun is off camera to the upper right. Venus's night side appears dark and rounded, surrounded by a bright crescent of light: the glare from its sunlit side. The stars Omicron (ο) Tauri and Xi (χ) Tauri can be seen in the first image (top).

Under pressure ▽

HUBBLE SPACE TELESCOPE/ALMA, 29 JULY 2021

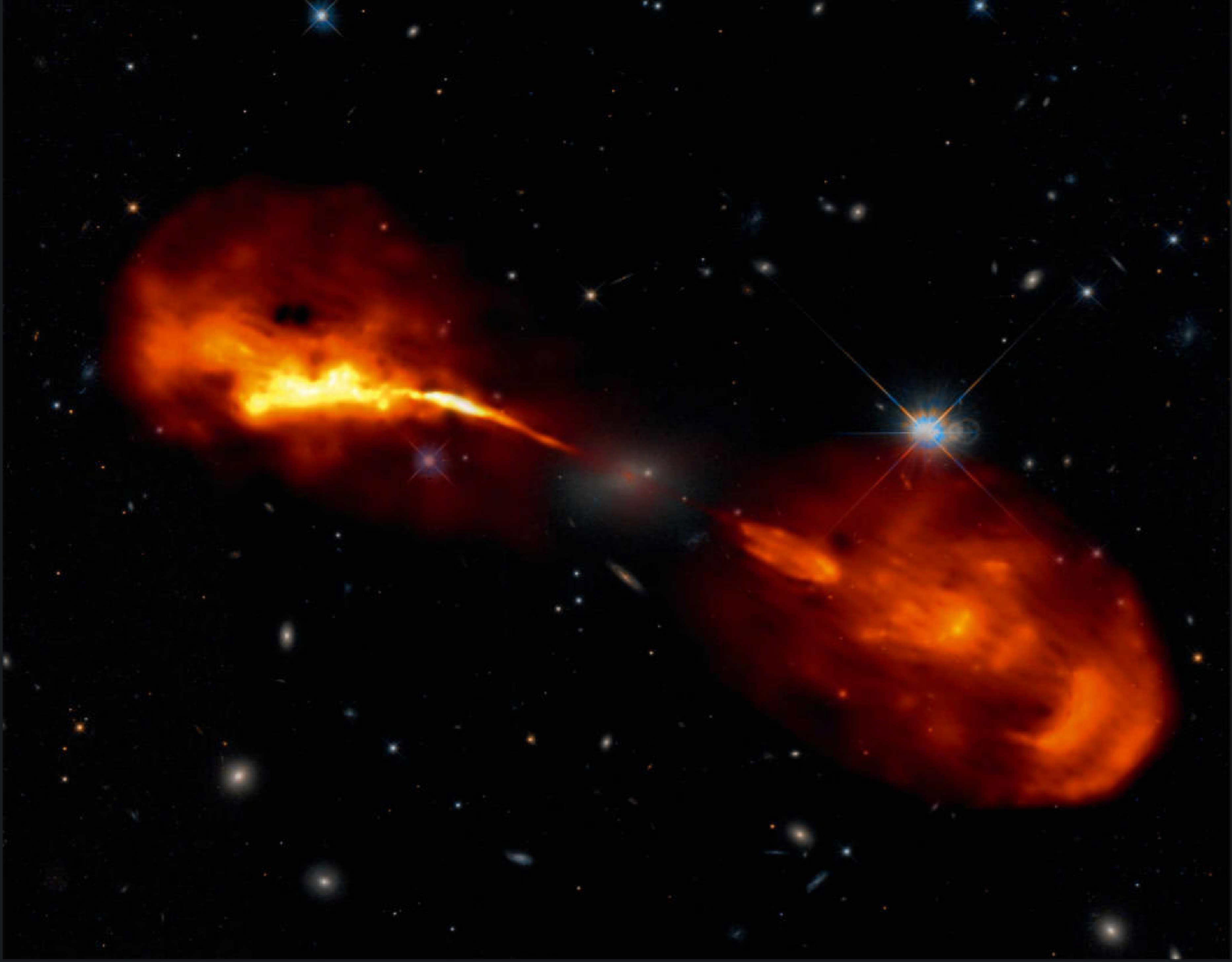
Gases stripped from galaxies may re-accrete and delay their death, scientists believe. Barred spiral galaxy NGC 4921 seems in its death throes, buffeted by its galaxy cluster, the Coma Cluster. Red/orange streaks reveal the filament structures left behind as its gas is stripped away in a process called ram pressure stripping. Without gas, eventually no new stars will form. However, new research shows that some gas is falling back towards its host, continuing star formation and slowing the galaxy's demise.

Pin-sharp planet

CURIOSITY MARS ROVER, 17 AUGUST 2021

NASA's Curiosity rover has captured a high-resolution 360˚ view of the Martian surface. The rover, which has travelled 26km since it landed in Gale Crater in 2012, reveals the terrain with great clarity. Stitched together from 129 photos, the centre of the image is 'Rafael Navarro Mountain', named after the scientist Dr Rafael Navarro-Gonzalez, who died of COVID-19 earlier this year. See a full video tour at **bit.ly/3BcxaCH**.

ESA/NASA/NRL/SOLOHI/PHILLIP HESS, ALMA (ESO/NAOJ/NRAO)/S. DAGNELLO (NRAO), NASA/ESA/HUBBLE/K. COOK (LLNL), L. SHATZ, NASA/JPL-CALTECH/MSSS, R. TIMMERMAN; LOFAR & HUBBLE SPACE TELESCOPE



△ Herculean effort

LOFAR, 18 AUGUST 2021

Supergiant elliptical galaxy Hercules A shoots out fast jets that grow stronger and weaker every few thousand years, according to new research. The study is one of a collection just published, using almost a decade's worth of data gathered by the Low Frequency Array (LOFAR). The network of 70,000 small radio antennae across nine European countries gives astronomers a 'lens' that is effectively 2,000km wide, which recently produced the most detailed-ever radio image survey of galaxies at frequencies around the FM radio band.

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The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

Sample slip-up for Mars rover Perseverance

Rock specimen appears to have crumbled when it was picked up

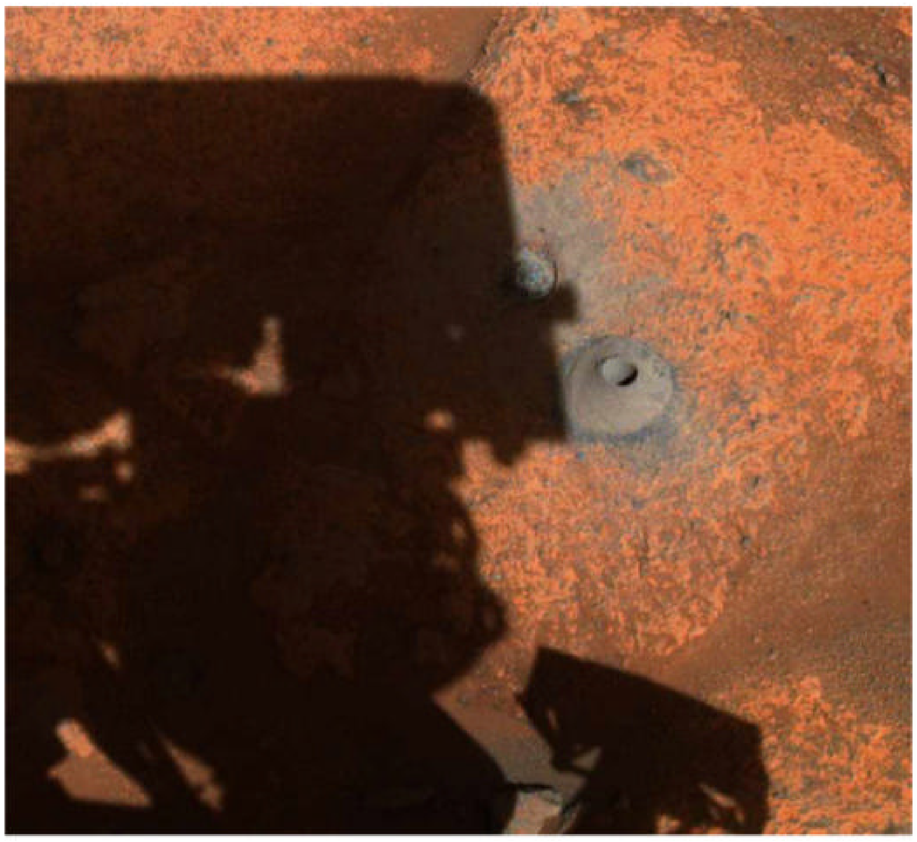
The first attempt to collect a sample from the surface of Mars using NASA's Perseverance rover ended in failure on 6 August. Fortunately, the fault seems to lie with the rock, not the rover, meaning Perseverance is still on track to complete its main mission of creating caches of samples for a future spacecraft to return to Earth.

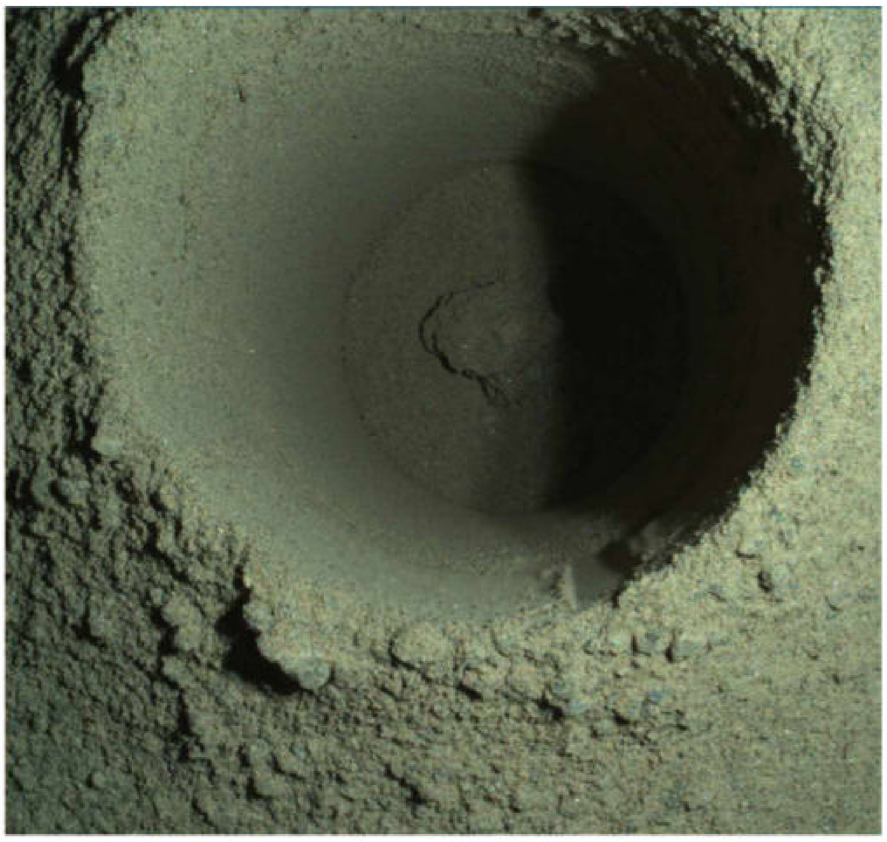
The rover made its first attempt at acquiring a sample after 164 sols (Martian days) on the surface. Initial feedback showed everything had gone to plan – the drill reached a depth of 7cm and the sample tube was successfully stored. When the team received a more detailed update six hours later, however, things didn't look as optimistic.

"Within minutes, the team noted that the volume probe indicated no sample was in the tube," said Jennifer Trosper, Perseverance's project manager, in an online report. "We quickly switched to problem-solving mode – once again trying to solve another problem tossed our way from the surface of Mars."

It seems the rock was far more powdery than anything encountered during testing and crumbled during collection. The team have now turned their eyes towards a region named Citadelle, further along Perseverance's planned route, where it is hoped the rocks have a more solid texture.

"We will first abrade the selected rock and use the science instruments to confirm (to the best of our ability) that the new target is likely to result in a core after the sampling process," says Trosper. The sampling routine will now also image the tube while it is still in the drill to confirm a sample was collected.
https://mars.nasa.gov





▲ **(Left:) Perseverance casts a shadow over the bore hole in the Martian surface; (right) the rock proved to be too powdery for a sample**

NASA/JPL-CALTECH/MSSS X 2

Comment

by Chris Lintott

Perseverance isn't the first lander to struggle with getting Martian soil where it needs to be – the stuff has been driving scientists mad for decades. I remember filming with the Phoenix team, as their joy at getting the craft safely down in the Martian arctic turned – slightly – to frustration: its soil sample had simply stuck to the lander's scoop rather than trickling into the instrument it was intended for.

More recently, the InSight lander's 'mole' – a heat probe designed to dig deep into the ground – failed to bite into the surface, leaving it stranded, a victim of the tendency for the soil to clump together.

All of these problems could be solved in seconds by an astronaut capable of wielding a brush (or, I guess, a spade in the case of the mole). It may be that the best argument for sending people to the Red Planet is just that its soil is quite so annoying!

Chris Lintott co-presents *The Sky at Night*

▲ An artist's impression of a planet orbiting the star L98–59; one of the worlds in its planetary system may be made up of 30 per cent water

ESO/M. KORNMESSER, NASA/DANIEL RUTTER, JOÃO ALVES/ESO VISIONS

Tiny planet could be water world

The body is the smallest exoplanet ever measured by looking at its star's wobble

A newly discovered exoplanet could be flooded by a global ocean. With a mass just half that of Venus, the tiny world is the smallest planet ever studied using the radial velocity technique, which looks for the wobble caused by the planet pulling on its host star to measure its size and mass.

The planet is one of three discovered around the star L98–59 in 2019 by the Transiting Exoplanet Survey Satellite (TESS), which searches the sky looking for the shadows cast by planets as they pass in front of their host stars. This method allows astronomers to measure the size of the planet, while also revealing that all three planets were probably small, rocky worlds. It also identified that several of the planets were in the star's 'habitable zone', where liquid water could potentially persist on the surface.

The trio of planets immediately attracted the attention of astronomers, who noted similarities to the inner planets of our own Solar System, especially as L98-59 is only 35 lightyears away. The Very Large Telescope (VLT) soon followed up the discovery, using the radial velocity technique to reveal the masses of the planets, which in turn allowed astronomers to work out their densities. This showed that two of the planets probably had some water while mostly being dry, but the third could be as much as 30 per cent water by mass – enough water that the whole surface would be flooded.

Astronomers are keen to understand the planet's atmosphere and hunt for any signs of water around the planet. However, the world is too small for such observations with the telescopes of today. Instead, it will have to wait for the next generation of telescopes such as the James Webb Space Telescope (JWST), due to launch later this year and ESO's Extremely Large Telescope (ELT), which is under construction in Chile's Atacama Desert and set to start observing in 2027.

"This [planetary] system announces what is to come," says Oliver Demangeon from Portugal's University of Porto, who led the study. "As a society we have been chasing terrestrial planets since the birth of astronomy and now we are finally getting closer to the detection of a terrestrial planet in the habitable zone of its star, of which we could study the atmosphere."

The team has also found 'hidden' exoplanets that had not previously been spotted in this planetary system. They discovered a fourth planet and suspect a fifth in a zone at the right distance from the star for liquid water to exist. "We have hints of the presence of a terrestrial planet in the habitable zone of this system," says Demangeon. **www.eso.org**

Scientists have been looking at how quasars, like CQ4479 here, are being fuelled by their spiral galaxies' shape

Galaxy arms feed hungry black holes

The structures slow down the gas until it falls to a galactic centre

Gas-guzzling supermassive black holes, known as quasars, are fed by their host galaxy's spiral arms scooping up gas for them to devour, according to a new set of computer simulations which looked at the gas flow throughout the whole galaxy, rather than just the region around the black hole.

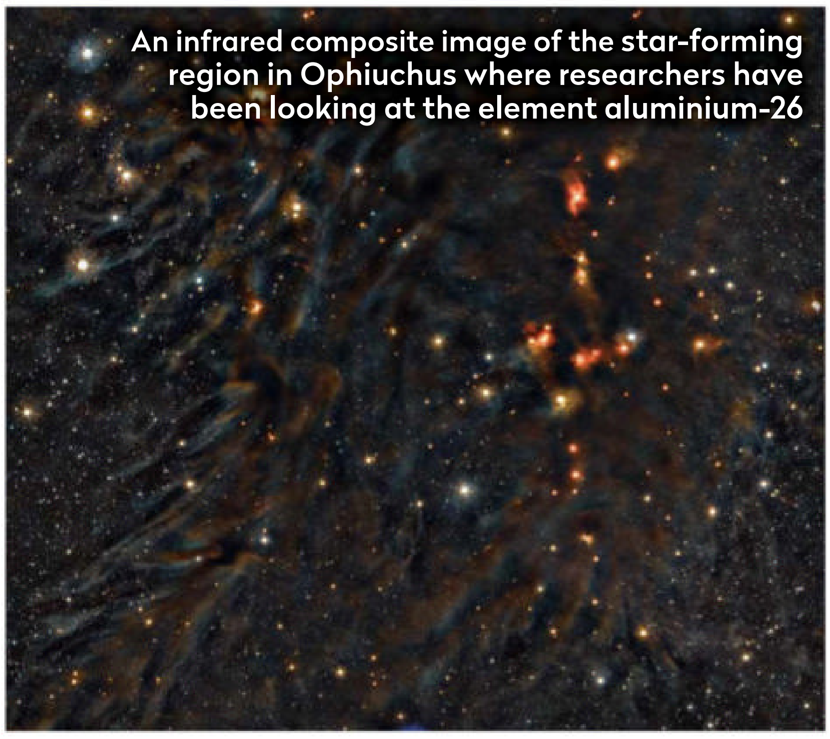
"The light we observe from distant quasars is powered by gas falling into supermassive black holes and getting heated up in the process," says Claude-André Faucher-Giguère from Northwestern University.

Quasars can swallow up to 10 solar masses of material a year, but astronomers have struggled to account for what funnels the gas towards the central black hole.

"Our simulations show that galaxy structures, such as spiral arms, use gravitational forces to 'put the brakes on' gas that would otherwise orbit the galaxy centres forever," says Faucher-Giguère.
www.northwestern.edu

Sun's supernovae siblings kept Earth warm

The source of the radioactive elements that helped keep early Earth warm may finally have been discovered, following investigations of a star-forming region in Ophiuchus similar to the one our own Sun is thought to have formed in.

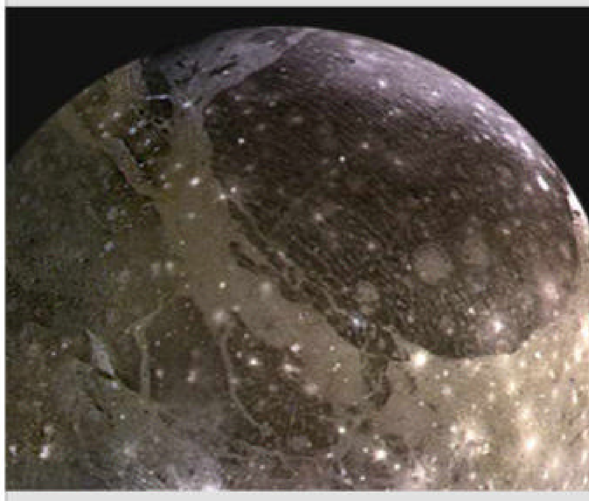


An infrared composite image of the star-forming region in Ophiuchus where researchers have been looking at the element aluminium-26

A team of astronomers looked at the infrared light given off by the gas clouds created by the young stars, as well as hunting down the gamma rays given off by the short-lived radioactive element aluminum-26, combining the observations to reveal that the element seems to be seeded into the nebula by the supernovae of highly massive stars. As new, longer-lived stars form in the region their planets would incorporate these elements, but the amount of aluminium-26 available could vary wildly from system to system.

"This matters for the early evolution of planetary systems, since aluminum-26 is the main heating source. More aluminium-26 probably means drier planets," says John Forbes from the Flatiron Institute's Center for Computational Astrophysics, who led the study.
www.simonsfoundation.org/flatiron

NEWS IN BRIEF



Water vapour on moon

A fresh look at archived Hubble data has shown evidence of water vapour in the atmosphere of Jupiter's moon Ganymede. It's thought the moon has more water than all of Earth's oceans, but that most of it is frozen 160km below the surface, and it's uncertain how the vapour might have made its way to the atmosphere.

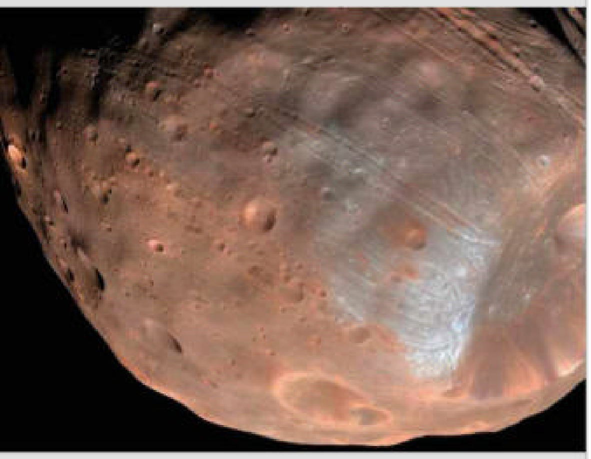
Early solar maximum

Solar Cycle 25 is heating up faster than expected. Sunspot numbers from July 2021 indicate activity could reach a maximum as soon as October 2024, meaning it would peak a few months before the earliest date previously predicted by a panel of experts back in 2019.

Starliner delayed

The second orbital test flight of Boeing's Starliner astronaut capsule has been delayed again after moisture was found in several of the vehicle's valves. The test was initially meant to occur in late 2020, but has been beset by delays. NASA hopes to use the Starliner to transport astronauts to the ISS.

NEWS IN BRIEF



Japan heading to Phobos

The Japanese Aerospace Exploration Agency (JAXA) is planning a space mission to bring samples from the Martian moon Phobos back to Earth by 2029. The mission aims to bring back 10g of material, and could also visit Mars's other moon, Deimos.

Bennu not a threat

Although asteroid Bennu will pass close to Earth in 2135 it is very unlikely to hit us, according to the latest analysis of its orbit using high precision-tracking data from OSIRIS-REx. The spacecraft circled the asteroid from 2018 to 2020, allowing astronomers to significantly reduce the uncertainties in the asteroid's orbit.

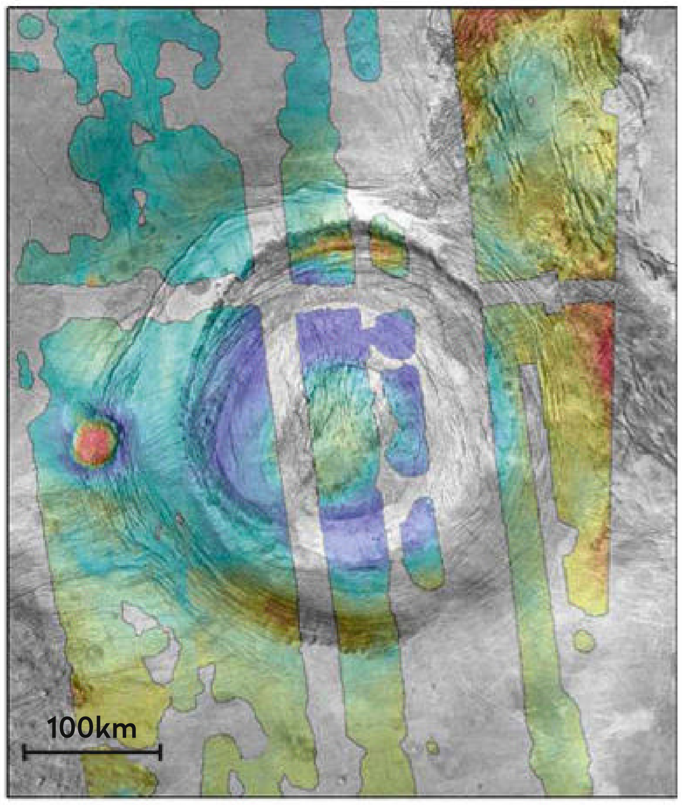
Mid-life stellar crisis

Magnetic fields could cause Sun-like stars to have a 'mid-life crisis', when they experience dramatic breaks in their activity and rotation rates. A new study shows the flow of charged particles from the star – the stellar wind – magnetically brakes the star's rotation, causing it to slow down over billions of years, becoming less active in the process.

BULLETIN

Recent volcanism seen on Venus

Planet may not have been dormant for as long as believed



▲ Scientists are looking at how Venusian volcanoes have deformed surrounding ground

Reports of Venus's death may be greatly exaggerated, as a fresh look at data from the Magellan spacecraft has found that volcanism could still be occurring on the planet today. Researchers revisited the data using techniques not available when Magellan visited Venus 31 years ago and carried out a large-scale analysis of the landscape.

"Instead of looking at the surface of the volcano or flows, we look at how it deforms the ground around it," says Megan Russell from the Planetary Science Institute, who led the study. "From this deformation we can infer properties like heat flow local to the volcano."

From the shape of these features, Russell's team could discern they may have formed within the last few tens of millions of years – which is recent, in geological terms – or could even still be growing. Either way, it appears volcanism has been happening on Venus more recently than believed. **www.psi.edu**

Origin of Curiosity site in doubt

For the last nine years. NASA's Curiosity rover has been exploring Mars's Gale crater under the belief the region was once a lake bed, but a new study from the Faculty of Science at Hong Kong University suggests this might not be the case.

Instead, the research suggests that the region was formed by sand and silt deposited by the wind, which was then soaked by ancient rainfall. The study found that immobile elements – meaning those that stay in the rock rather than dissolving in water – are richer at higher elevations, which is normally seen in wind-blown soils rather than lake deposits. There also appears to be depleted iron levels, suggesting the atmosphere was more like an arid desert than a wet lake.

Planetary geologists aren't quite willing to throw away everything they know about the crater just yet, and will continue to investigate.

Could the sediments seen here be the result of wind rather than water?

"The data presents challenges to existing hypotheses for both the depositional environment of these rock formations and the atmospheric conditions they formed after," says Hong Kong University's Ryan McKenzie. "This work will inspire new and exciting directions for future research." **http://mars.nasa.gov**

The tide is turning

When it comes to ocean-bound plastic pollution, enough is enough. Step forward the unique C60 #tide. A superlative dive watch with a neon-like sapphire dial and chronometer certified movement, it delivers power, accuracy and toughness in equal measure. But that's only half the story. Thanks to our partnership with social enterprise, #tide, the watch's case-back inserts and strap are made from 100% recycled ocean plastic (though you can also choose a marine-grade steel bracelet). Which makes for a healthier ocean. And a watch you'll take pride in wearing.

You can read more about the C60 #tide in the new issue of Loupe, our complimentary watch magazine. Sign up for yours at christopherward.com

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Ingeniously English.
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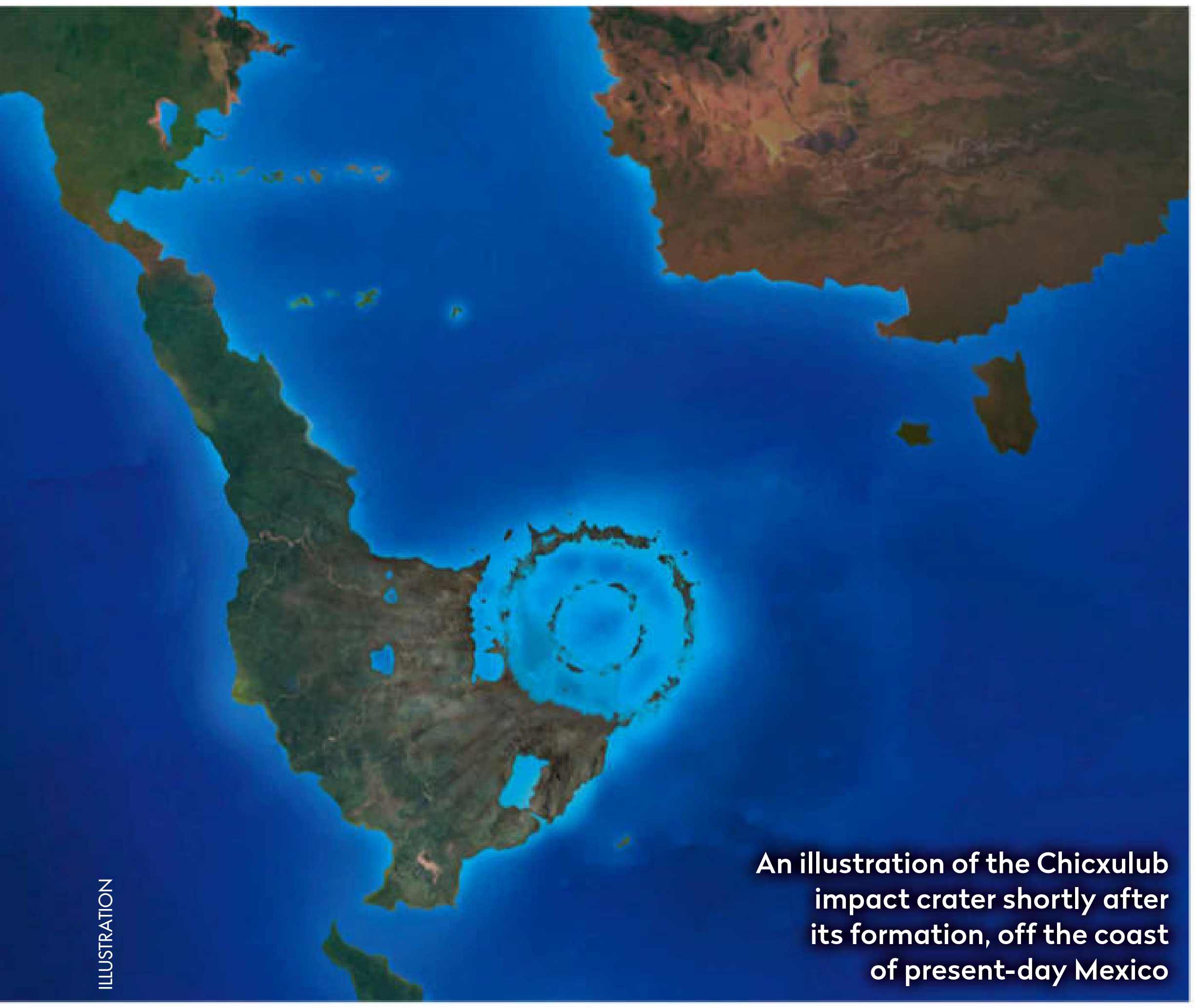
Our experts examine the hottest new research

CUTTING EDGE



An illustration of the Chicxulub impact crater shortly after its formation, off the coast of present-day Mexico

ILLUSTRATION

Tracking down a dinosaur killer

Scientists think they've found the origin of the meteor that killed the dinosaurs

For many years now, it's been well established that the mass extinction at the end of the Cretaceous period – which led to the extinction of the dinosaurs as well as the loss of 75 per cent of all plant and animal species on Earth – was associated with a huge impact. The Chicxulub crater, buried beneath the Yucatán Peninsula in Mexico, was identified in 1990 as a giant impact feature – some 150km across and 20km deep (although by now well filled-in with sediments). The calculated formation of this crater coincides with the mass extinction, around 66 million years ago, and the impactor is believed to have been an asteroid about 10–15km in diameter.

The Chicxulub crater is one of the largest impact structures ever found on Earth. But there's something else exceptional about this impact. It seems that the crater was created by a carbonaceous chondrite (CC) asteroid – a dark rock full of organic compounds. This is surprising because impacts from this sort of object are rare – they make up only five per cent of all meteorites collected. So why is it that one of the largest craters on Earth – and the impact that wiped out the dinosaurs – was formed by such an asteroid?

Measuring impacts

David Nesvorný and his colleagues at the Department of Space Studies, Southwest Research Institute, in the US, have been trying to get to the bottom of this mystery. They built a computer simulation of how the orbits of objects in the main asteroid belt can be dislodged to become near-Earth asteroids that have the potential to collide with our planet. Their model included over 42,000 asteroids with widths greater than 5km in the main belt, and how they're affected by influences such as the radiation pressure of sunlight or Jupiter's gravity.

They calculated that Venus and Earth receive about the same number of strikes from asteroids bigger than 5km, with Mars being hit about three times less. Interestingly, Nesvorný found that about six per cent of the simulated Venus impactors had evolved into a retrograde orbit beforehand – equivalent to cars colliding head-on with a much higher impact speed – and hit the planet at a staggering 220,000km/h.

"The Chicxulub crater is one of the largest impact structures ever found on Earth. But there's something else exceptional about this impact"

But what about the composition of the largest impactors, such as the Chicxulub asteroid? Nesvorný and his colleagues found that because of the orbital dynamics involved, smaller impactors (less than a kilometre in diameter) are most likely to have come from the inner edge of the asteroid belt, so have an ordinary, stony composition – as found with most meteorites discovered. But the largest impactors hitting Earth are more likely to have originated from the middle or outer asteroid belt, where CC objects are more common. They conclude that the impactor that triggered the mass extinction 66 million years ago was a main-belt asteroid that quite likely (they calculate around 60 per cent probability) originated from beyond 2.5 AU.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Dark Primitive Asteroids Account for a Large Share of K/Pg-Scale Impacts on the Earth* by David Nesvorny et al. **Read it online at: https://arxiv.org/abs/2107.03458**

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, HUBBLE/ESA/D M CLARK X 2

Planetary nebulae made pretty by debris

Dying stars wrap themselves with their own detritus, and it's beautiful

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

One of the first objects I looked at through a telescope was the Ring Nebula. There was something about the neatly coloured doughnut that appealed, though I soon found that seeing more than a smudge is difficult – even through a large telescope. In images, though, especially those that flowed from the Hubble Space Telescope, the complexity of these fragile objects became obvious.

In addition to rings, there are planetary nebulae that look like egg timers, nebulae shaped like butterfly wings and even a singular object that goes by the name of the Red Rectangle. Close up, there are substructures – ribs, stripes and more – and it's these smaller scale features that this month's paper sets out to explain. Its authors concentrate on hourglass-shaped nebulae, several of which seem to display faint filaments that the paper describes as a 'spiderweb' structure.

The Hubble image of the Matryoshka Nebula (right) shows how complicated such objects can be. A bright central source sits in the middle of the hourglass, the sides of which seem made of almost-transparent gossamer, with a texture that hints at unresolved structure. Material is believed to be flowing away from the central source and the whole thing sits in a larger, oval nebula consisting of long, curving arcs of glowing cooler gas. Whatever is sculpting these structures, it produces symmetry, both north-south through the hourglass lobes and east-west in the spiderweb structure.

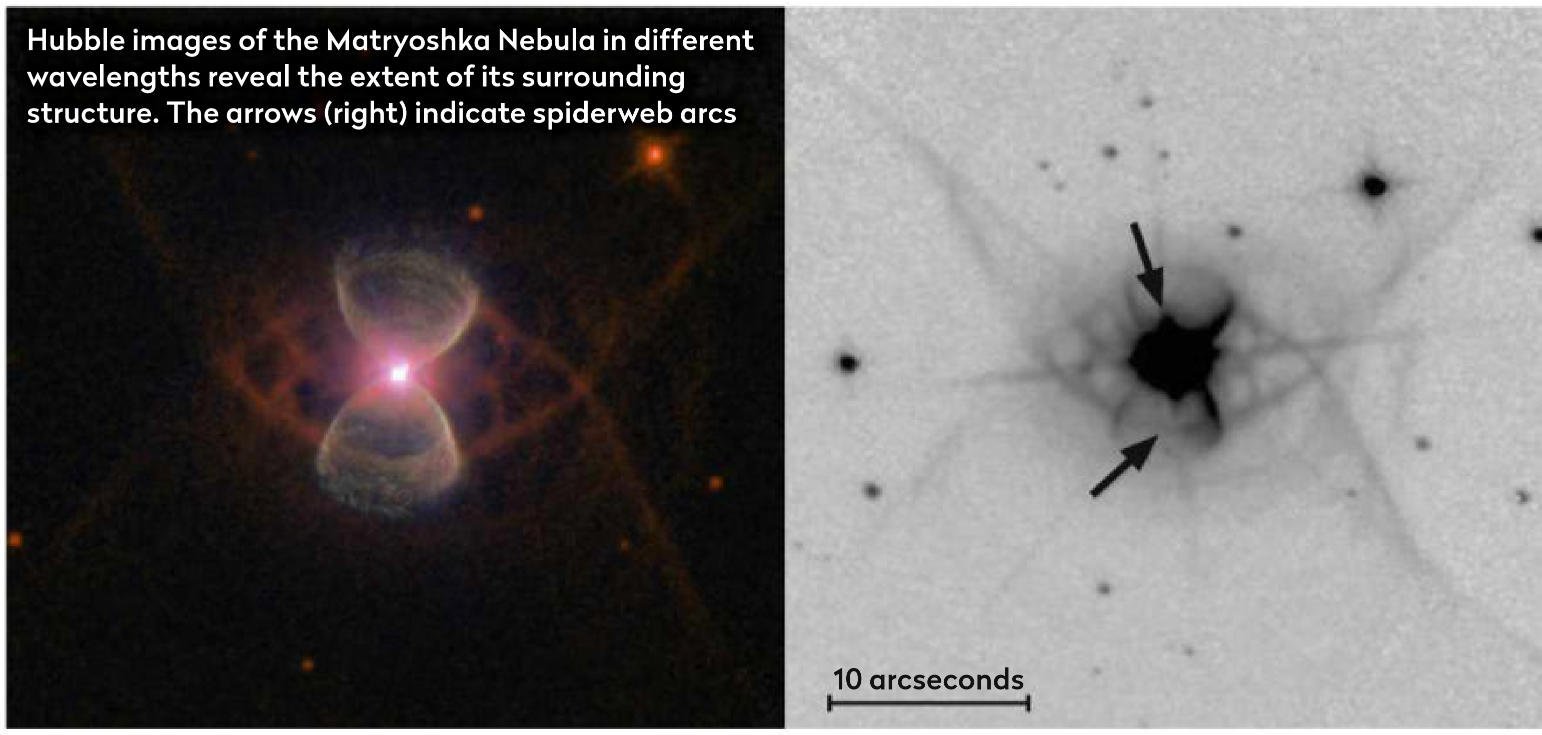
So what's going on? The basics we know; planetary nebulae such as this are formed during the later stages of a star's life (the Sun, for example) as instability at the core causes the outer layers of the star to be shed. As a result, the beauty of these objects is transitory; something like the Ring Nebula will exist for only a few tens of thousands of years. As the stellar wind pushes material away from the star, it can excite and interact with surrounding material, creating the structures we see.

"In images, especially those that flowed from the Hubble Space Telescope, the beauty and complexity of these fragile objects became obvious"

The key insight of the model in the paper, though, is that the planetary nebulae we see today don't exist in a pristine environment. The process of atmosphere loss is erratic and takes time, so the star exists surrounded by its own debris. Some of this material, the authors say, must be falling back onto the star and their detection of what seems to be an accretion disc around the central source suggests that there is enough material to make a difference.

More than meets the eye

When gas is moving, it can become shocked and excited, and it seems like this process can weave the spiderweb structures that we observe. If the inside of the hourglass is a region where material flows outwards, its edge is a place where material can flow back. This process is likely to be somewhat chaotic and what appeared to be a precious, permanent jewel in the sky is revealed to be a dramatically dynamic system, as changeable as the pattern of waves on the surface of the sea.

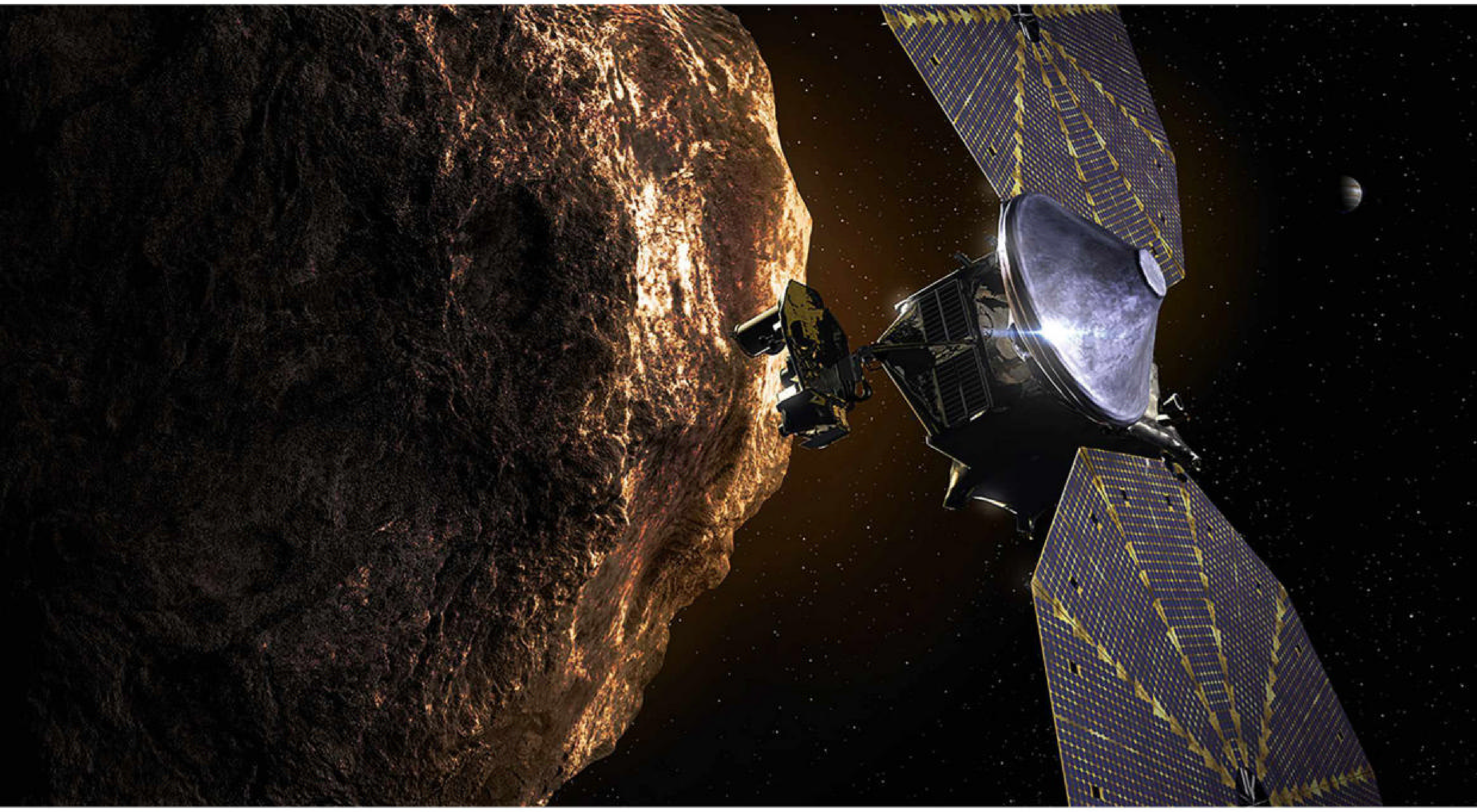


Hubble images of the Matryoshka Nebula in different wavelengths reveal the extent of its surrounding structure. The arrows (right) indicate spiderweb arcs

Chris Lintott was reading… *Fallback in Bipolar Planetary Nebulae* by Willem A Baan et al.
Read it online at: https://arxiv.org/abs/2107.14269

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **An artist's impression shows the Lucy mission passing a Trojan asteroid near Jupiter. The mission will help scientists to unlock clues about the early Solar System**

SOUTHWEST RESEARCH INSTITUTE, NASA/JPL X 2

Carly Howett will field Solar System questions in September's episode of *The Sky at Night*, but she will answer her own when Lucy takes flight

On 16 October 2021 the launch window for NASA's Lucy mission opens. It will study Jupiter's poorly understood Trojan asteroids. These space rocks are remnants of the Solar System's formation, and will provide astronomers with a valuable insight into how our planetary system formed – like archaeologists piecing together the lives of the ancients. Space missions show little regard for sleep schedules, however, so the launch window opens at 5:34am and lasts about an hour. If the spacecraft is unable to launch in that window (for example if the weather is bad) then we will be back bright and early the next day, and the next, until it launches.

The Trojan asteroids share an orbit with Jupiter, orbiting the Sun either ahead of or behind the gas giant, in regions known as Lagrangian points. Here, the gravitational pull of Jupiter and the Sun equals the centrifugal force felt by small bodies in orbit – so they can remain in place for billions of years. Most of Jupiter's Trojans are located at its L4 Lagrangian point, which moves ahead of Jupiter in its orbit, so that's where Lucy is headed first. It will make flybys of four different asteroids between August 2027 and November 2028 studying their surface composition, geology and interiors. Then Lucy is headed to the L5 point trailing behind Jupiter, where it will arrive five years later to study a binary Trojan asteroid.

Little is known about the Trojan asteroids because they are dark, small and far from Earth – making them very difficult to observe. In fact it was only recently discovered that one of the first asteroids to be encountered by Lucy, Eurybates, has a moon!

Yet how and where these asteroids formed is an intriguing question, since it provides an important clue to how our entire Solar System formed. One idea is that the Trojans formed at the same time and close to the same location as Jupiter, eventually becoming captured by Jupiter's enormous gravity.

Carly Howett is an associate professor at the University of Oxford and an instrument scientist on the Lucy mission

This implies that their composition is similar to Jupiter's early in its formation (its runaway growth and gas accumulation coming later). The second hypothesis is that the Trojans formed much further out from the Sun – in the Kuiper Belt beyond Neptune – and were scattered into the inner Solar System when a big reshuffle of the large outer Solar System planets occurred. In this scenario the change in gravity caused by the reshuffle kicked the Trojans inwards, where Jupiter captured them.

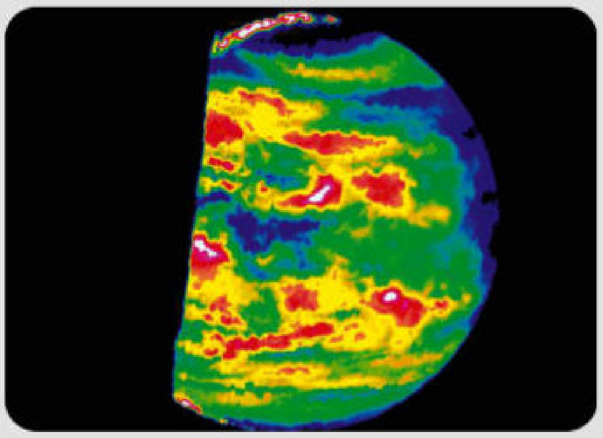
Even though the first scenario seems more plausible it is deemed less likely, as it cannot explain aspects of the Trojan population that the second one can – for example why some of the Trojans have such large tilts in their orbits.

Lucy will help settle this dispute, by enabling the composition of the asteroids to be determined at high spatial resolutions. For example, if the asteroids are shown to have compositions similar to Jupiter's moons then this implies that they formed close to Jupiter. However, if the asteroid composition is more similar to the Kuiper Belt objects seen by New Horizons (Pluto, Charon and Arrokoth), that implies they formed far from the Sun, and a cosmic reshuffle early in our Solar System formation did take place. Either way, the results promise to be fascinating.

Looking back: The Sky at Night

11 October 1992

On 11 October 1992 episode of *The Sky at Night*, Patrick Moore was joined by David Allen, acting director of the Anglo-Australian Telescope (ATT) at the Siding Spring Observatory in Australia. Allen had been using the telescope to study the atmosphere of Venus, complementing the observations of the Magellan spacecraft, which was in orbit around the planet at the time.



▲ **Spectograph mapping of Venus in infrared reveals the planet's thermal profile**

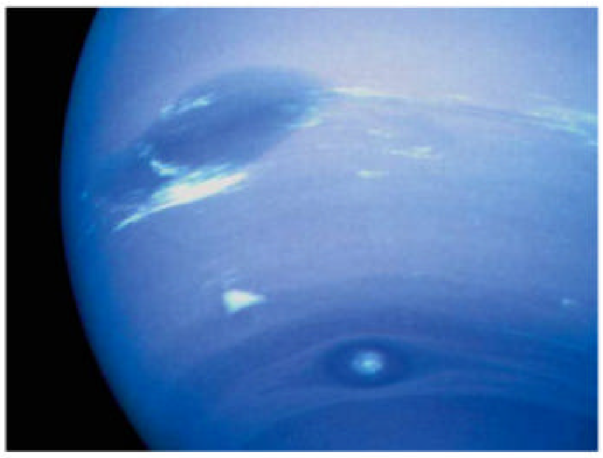
That October, the ATT was conducting a new set of observations, using its spectrograph to map out the planet at several infrared wavelengths, revealing details about the planet's structure and thermal profile. The spectrograph used a slit to single out a specific wavelength, however, meaning it could only image one point in the sky at a time and had to laboriously scan across the surface.

While most of the infrared light hitting Venus is absorbed by the upper atmosphere, Allen's work revealed that there were 'infrared windows', where the atmosphere was transparent to a specific wavelength. These play an important part in how the planet regulates its temperature. Earth has several similar windows, and so by studying the difference between the two planets, planetary scientists are able to begin understanding why Earth maintains its temperate, life-sustaining temperature while Venus has turned into a global hot house.

The Forgotten Solar System

Jupiter, Saturn, Mars and Mercury have been explored by numerous spacecraft, but Neptune and Uranus have only been glimpsed once, by Voyager 2. Are the ice giants worthy of further investigation? Maggie and Chris find out what missions to the outer Solar System might discover, and the window of opportunity that could see a spacecraft arrive in 2043.

BBC Four, **10 October**, 10pm (first repeat
BBC Four, **14 October**, 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ **Voyager 2 captured Neptune's Great Dark Spot when it flew by in 1989**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2022* and Robin Scagell's *Guide to the Northern Constellations*

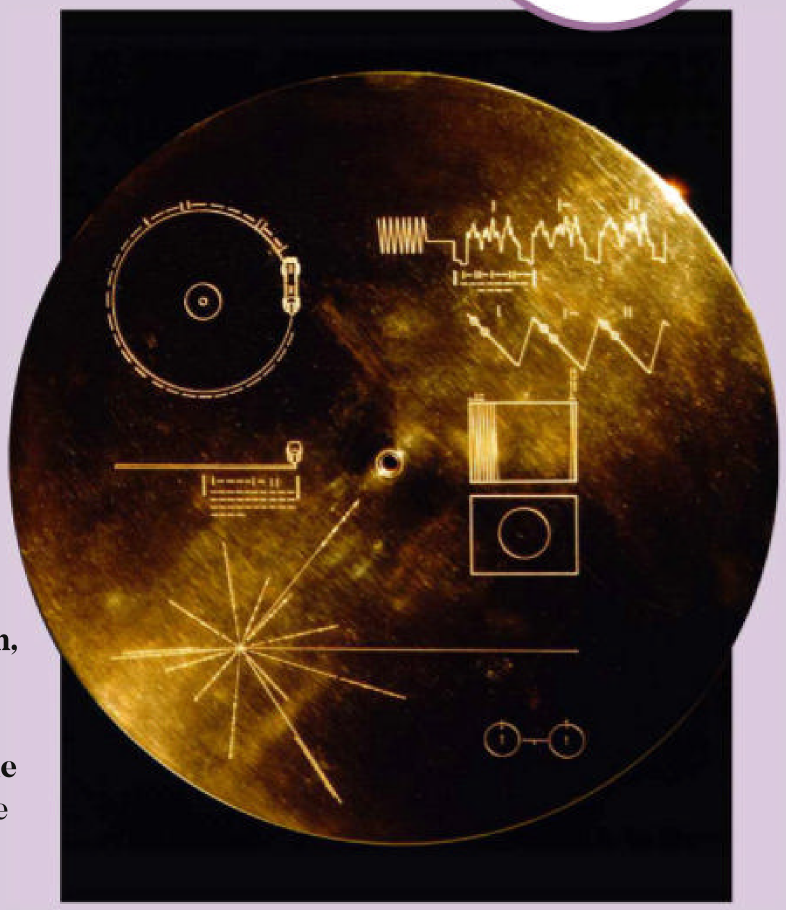
Winner's details will be passed on to Octopus Publishing to fulfil the prize

MESSAGE OF THE MONTH

Addressing Earth

I need to know the answer to a very important question; it's one that my children asked me the other day. The question was: what is the planet Earth's Universal address? For example, if someone from a distant planet wanted to send me a letter or a parcel in the post, what address would they need to put? I hope you can provide me with this important information, which needs to be 100 per cent accurate.
David Mitchell, Southampton

That's a very interesting question, David! Your Universal, or cosmic, address would be your postal address, followed by: **Earth, Solar System, Oort Cloud, Local Interstellar Cloud, Local Cavity, Orion Arm, Milky Way, Local Group, Virgo Supercluster, Laniakea Supercluster, the Universe**. It's challenging to provide an accurate address, though, since it will depend on our own frame of reference on the Universe, which could be very different where you're sending the parcel; and in the time it takes to deliver, everything in the Universe will have moved! ***– Ed.***



▲ **The Voyager mission's Golden Record includes a diagram of pulsars (bottom left), indicating where Earth is in relation to the rest of the cosmos**

Tweet

Paul Martin
@Tyrone_skies • 12 Aug
#Perseids put on a good show last night for us up at Beaghmore. Caught two meteors in one frame alongside a beautiful Milky Way. #darkskies @StormHour @omdarksky @VirtualAstro @ThePhotoHour @skyatnightmag @UKMeteorNetwork @barrabest

Shoot for the Moon

I've been meaning to send in my first attempt at catching a photograph of the Moon rising and I've eventually got around to it. I turned 40 on 22 July and asked for a monocular and stand as a present.

I got into stargazing, Moon watching and tracking the International Space Station (ISS) while I was shielding due to COVID-19 last year and again this year, and I thought I'd pass the time with something new. For my birthday I received a 12x55 high definition monocular with a smartphone attachment. With a bit of beginner's luck I managed to capture the Moon rising with a tree and a wind turbine on the horizon (see picture, left). I've got a lot more work to do with focusing and steadying the stand, but I can't believe the start I'm off to!
Stuart Wallace, Ballyclare

Fit for the Sun

In response to your reply to Colin Anderson in the September issue ('Scope Doctor', page 19), in which he wanted to fit the whole disc of the Sun into his image: he asked if he could use a focal reducer and you laid out why this wouldn't work. I wanted to let Colin know that he could achieve what he wanted with his Newtonian, and fit the whole disc of

NASA, CELESTRON

the Sun into his image, by using a camera with a larger sensor to capture more of the light cover. He may already have a DSLR camera to hand which would do the job; a DSLR with a smaller APS-C size sensor would work, as his Hypercam 183C has a sensor size of 13.2mm x 8.8mm, while an APS-C sensor is 25.1mm x 16.7mm.
Stuart Buchanan, via email

Hazy view

On the morning of 17 August, I looked out of the window in the early morning and the Sun had just risen above the horizon (it was shining through haze and was safe to look at). It appeared much larger than when high in the sky. Could it be that the 'Moon illusion' is not confined to the Moon?
AJ Bills, Harrogate

It could well be the case the Sun appears larger when close to the horizon, as it's the way humans perceive the outside world that creates the optical illusion. However, please don't take any more risks with your eyesight: looking at the Sun even through cloud isn't safe. The sunlight may be less intense, but its UV light can still damage the photoreceptors at the back of your eyes. If you do any solar observing with the naked eye, you should always use eclipse glasses. ***– Ed.***

Lunar puzzle

I took two photos last year, which have been puzzling me. They were taken from my back garden after I finished my night shift and the detail [EXIF data] attached to the photos says they were taken at 6.19am on the 12 November 2020. I vaguely remember something about an eclipse at that time, but I can't find any more info. The first ▸

ON FACEBOOK

WE ASKED: What are your top tips for observing and imaging under the light pollution of cities?

Darshna Ladva I'm in Stanmore, London, and you can image here. You either have to manage your exposure times or use a light pollution filter; it all depends on your target and kit.

Brendan Scoular I try to observe after midnight when it seems that the atmospheric conditions stabilise to offer better viewing. That, coupled with my neighbours' garden lights going off at 11:30pm, certainly helps.

Denis Pius Some astrophotography tips:
1. Avoid direct light to your lens. Set your camera in a place with no streetlights, or block the light hitting your lens.
2. Avoid bouncing light. Don't set your camera lens facing a wall that bounces light from behind or the side.
3. Use a lower ISO. Normally in the city I use ISO 800; if there are streetlights nearby I use ISO 400.
4. Separate the foreground and the sky with different shutter speeds and blend together in postprocessing.

Nick Williams I use a star tracker and light pollution filter on my DSLR camera. By stacking 30x 2' exposures at ISO 400, I even managed to image the Milky Way in Chingford, London.

Paul Adamson I live in Somerset under a dark pristine sky, but I've spent most of my life in London. That's how I came to learn the constellations as it was only the brightest stars that I could see. The planets and Moon are no problem anywhere.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies
With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I recently purchased a Celestron StarSense Explorer LT80AZ. I've aligned it and set it up with my mobile phone, but even though I can see terrestrial objects I can't see celestial ones. Where am I going wrong?
MAGGIE MURRAY

You mention that you can see terrestrial objects but not celestial ones, so the telescope and eyepieces themselves are working. This suggests that we need to revisit the fundamentals of night-time observing.

Your telescope comes with a star diagonal, two eyepieces and a Barlow lens so select the eyepiece marked 25mm and insert it in the diagonal. For now, dispense with the smartphone app, simply point the telescope at the sky on a clear night when it has got truly dark. Ensure that the dust cap is removed (yes, it happens!) and that there is no nearby extraneous light, then position your eye centrally over the eyepiece. Gently rotate the focus knob to move the focus tube fully in and then out until you reach the point at which you can see stars. Make very fine focus adjustments until the stars are as small as possible to attain accurate focus. Now you can start searching the sky for other objects either with or without the app.

▲ Ensure you've got a sharp focus before locating targets with the Celestron StarSense Explorer LT80AZ

Steve's top tip

What is chromatic aberration?

The glass lenses in a refractor bend or 'refract' the light from distant objects and focus it at the focal plane. However, simple glass lenses can't focus all the colours of light to exactly the same focus position because the refractive index of glass varies with the wavelength of the light passing through it. This phenomenon results in coloured halos around bright stars and colour casts on opposing edges of the Moon and planets. This optical issue is known as chromatic aberration and telescope designers use special low dispersion glass (ED glass) and two or more different glass elements to try and alleviate the problem.

Steve Richards is a keen astro imager and an astronomy equipment expert

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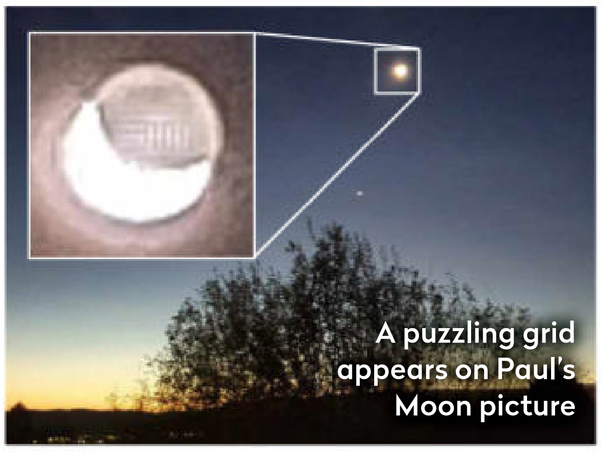
▸ photo is from my back garden and the second is an enlargement of the Moon. Do you have any idea what the grid is on the Moon? Thanks in advance for your help!
Paul Mitchell, via email

The grid on the Moon is certainly unusual, Paul! It's hard to be definite without knowing the camera and software used, but it could be an unwanted artefact (noise) on the image from the camera sensor. The only eclipse in November 2020 was a penumbral lunar eclipse on the 30th, visible from the UK as the Moon set; it's possible that the time and date settings on your camera may need to be reset. ***– Ed***


A puzzling grid appears on Paul's Moon picture

Instagram

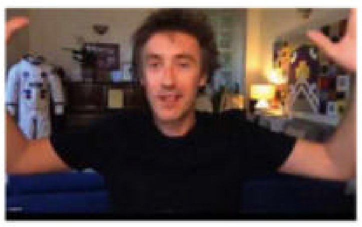

rob.barsa • 9 August

This photo depicting the observation of the #Perseids meteor shower was created near a small village, Mníšek nad Hnilcom, in eastern Slovakia. It shows many meteors and demonstrates that all the Perseids are identified by the radiant in Perseus from where the meteor paths appear to originate. It also shows a group of amateur astronomers performing visual observation. @universetoday @thisisslovakia @bbcskyatnightmag @twanight

CORRECTION

• In the feature 'Late summer variables' (September 2021 issue, page 72), in the wider-field locator chart for R Scuti, the star near R Scuti was labelled wrongly as Beta Cygni. Beta Cygni was also mentioned in the caption. This should be Beta Scuti in both cases.

SOCIETY IN FOCUS


▲ **Dallas Campbell gives a Zoom talk to The Flamsteed in May 2020**

FLAMSTEED ASTRONOMY SOCIETY

The last day that members of the **Flamsteed Astronomy Society** met together for a main monthly lecture was on 9 March 2020 – though we didn't know it at the time. We had an inkling that travel restrictions might make it difficult for guest speakers to travel to our home at the Royal Observatory Greenwich (ROG), so we explained to our members that night that we were looking at the possibility of moving talks online.

Two weeks later, the UK was in lockdown, but we had already trialled Zoom with our members, who welcomed the opportunity to keep our talks going. Silver linings in this COVID-19 cloud are few and far between, but we found we could accommodate more of our members at an online event than we could squeeze into our National Maritime Museum lecture theatre. The internet enabled us to bring speakers 'to Greenwich' who might not have been able to travel so far, even in 'normal' times. We've welcomed a range of lecturers – from Prof Dame Jocelyn Bell Burnell and Prof Catherine Heymans, to science writers Dallas Campbell and Jo Marchant, while our 'history of astronomy' programme didn't skip a beat.

Although our usual observing sessions have been cancelled, as have various visits, we have run astrophotography workshops online and a three-part 'Introduction to astronomy' series.

But, as of the time of writing, we are all eagerly awaiting a return to 'real world' events and being a more 'social' society. It will be good to be back in our usual space.
Andy Sawers, former Chair of the Flamsteed Astronomy Society, 2016-21
▸ **www.flamsteed.info**
▸ **www.vimeo.com/flamsteedas**

COVID-19
Online and socially distanced events taking place this month

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

PICK OF THE MONTH

▲ View a selection of the world's best astrophotography at the National Maritime Museum

Astronomy Photographer of the Year 2021

National Maritime Museum, Greenwich, London, starts 18 September

You can always find top-flight astrophotography in the APY finalists and this year's prize-winners knock it out of the park once again.

From now until next summer, London's National Maritime Museum hosts an exhibition of all the winning images, along with some of the best shortlisted entries. You'll find photos of nebulae, the Sun, star trails, aurorae, our Moon, comets and more, picked from the 4,500 entries sent in from all over the world. There's also the Young Photographer and Best Newcomer winners, and the Annie Maunder Prize for Image Innovation. See **www.rmg.co.uk/astrophoto** for details.

Live Exmoor Dark Skies Festival

Exmoor, 22 October–7 November

Enjoy events for families and adults taking place all over Exmoor, including stargazing suppers, guided night walks, dusk safaris and expert astronomy talks. For details visit **bit.ly/2YbtM9P**

Live Moffat dark sky walk

Dumfries and Galloway, 2 October, 8pm

A night-time walk up Gallow Hill in Moffat, a village with International Dark-Sky Community status, including a guided talk about the stars and constellations. Tickets are £15. See **bit.ly/3s3vB6A**

Live Scilly Dark Skies Week

St Martin's, Isles of Scilly, 2–9 October

A celebration of grassroots astronomy with stargazing, workshops and speakers, including astrophotographer extraordinaire Damian Peach. Tickets are £175 and include entrance to all the events and guided use of the observatory. Email **cosmosscilly@gmail.com** to book. Day passes are available nearer the date.

Live LAS Equinox Sky Camp

Kelling Heath, Norfolk, 4–11 October

The largest star party in the UK returns, featuring expert talks and stargazing. If the weather is uncooperative, peruse the huge range of telescopes and equipment at the trade stands and secondhand stalls. See **las-skycamp.org** for details.

Live Apollo: A Moon Odyssey

Cavendish Road Primary School, West Didsbury, Manchester, 11 October, 7pm

West Didsbury Astronomical Society welcomes guests to author Andrew Lound's dramatic telling of the Apollo story, illustrated with images, scale models, sound and music. **bit.ly/37vpeiU**

Live Northumberland StarFest

Bellingham, Northumberland, 27–29 October

A two-night astronomy-themed break with three days of workshops and presentations, including 'Get to Know Your Telescope' and 'Rocket Building and Launching'. Tickets from £380 for two, including all events, use of telescopes and binoculars, meals and luxury accommodation. **astro.ventures/stargazing-festivals/darkskyfest**

Online Tenerife observing session

29 October, 8pm

Join a Zoom talk from Mid-Kent Astronomical Society about how to access the Open University's robotic telescope situated under the dark skies of Tenerife, plus a bonus real-time virtual observing session. Non-members are £3; contact **membersec@midkentastro.org.uk** (36 hours ahead) to join the Zoom.

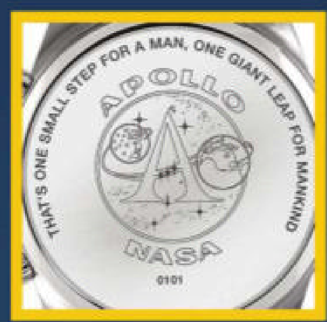
'That's one small step for a man, one giant leap for mankind'

APOLLO 11

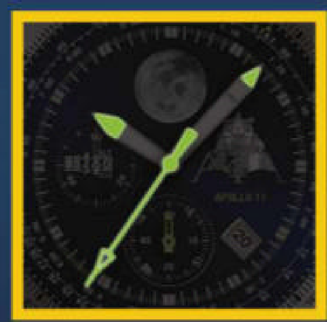
MEN'S CHRONOGRAPH WATCH

In 1961, President John F. Kennedy set a goal of landing a manned spacecraft on the moon's surface. On the 20th July 1969, science fiction became reality as the crew of the NASA's Apollo 11 mission set foot on the moon, with the words: *'That's one small step for a man, one giant leap for mankind'* broadcast to the waiting millions on Earth.

Reverse is uniquely numbered and engraved with official emblem of NASA's Apollo space missions



Face depicts the Lunar Module accented with rich silver-plating



Glow-in-the-dark hands for easy viewing, day or night

Individually numbered

Now, NASA's Apollo 11 mission and the new era of space exploration it inspired is commemorated by a new chronograph watch. The *Apollo 11 Men's Chronograph Watch* is an original design, only available from The Bradford Exchange.

A unique design with precision chronograph dials and stainless steel casing

Expertly handcrafted, this durable stainless steel chronograph watch with matching strap depicts the Lunar Module accented with rich silver-plating against a detailed watch face, and an image of the Moon at the top of the watch face. Featuring two chronograph dials with stop-start timing and a date function. Luminous hands and markers make it easy to view the time day or night! The casing reverse is engraved with the official emblem of the Apollo space missions featuring NASA's Apollo 'A' flanked by the Earth and Moon. The quote heard around the world: *'That's one small step for a man, one giant leap for mankind'*, frames the Apollo mission emblem, whilst individual numbering makes each watch truly unique.

Not available on the high street – order your chronograph watch now!

This market-first will be accompanied by a custom-designed presentation case, a Certificate of Authenticity and our 120-day money-back guarantee. It will be available for just 5 interest-free instalments of £27.99 – that's only £139.95 (plus £12.99 S&S)*. Pay nothing now – simply complete and return your Priority Order Form today.

Watch case measure 1.4 inches (3.8 cm) in diameter excluding crown.
Strap measures 7.9 inches (20 cm) in length (excluding casing and buckle).

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FIELD OF VIEW

'New Astronomy' is bringing space to us all

On Earth and in orbit, Laurent Marfisi considers the democratisation of space

Laurent Marfisi is the CEO of Unistellar. He incorporated groundbreaking technology into the first Unistellar eVscope

We're seeing the dawn of a new era of space exploration. This July, tourists took two trips to the edge of space aboard private missions. Richard Branson's VSS Unity spaceplane flew him and three other passengers to an altitude of 85km above our planet. Nine days later, Jeff Bezos followed onboard his New Shepard rocket.

Both trips launched a small group of lucky individuals into what has long been a dream for many: to go to space. Today, the so-called 'New Space' industry is promising to revolutionise the way humans think about the cosmos. Some day soon, space may be part playground and part goldmine for tourists and entrepreneurs.

But with the sky-high price of tickets to space, the final frontier is still far away for most of us. Thankfully, another way of accessing space is also more attainable today than it's ever been before. This new era of technology that gave rise to Blue Origin, Virgin Galactic and SpaceX is paralleled by a similar, and way more democratic era of 'New Astronomy' for telescopes, which gives everyone an opportunity to explore the stars.

In the growing New Astronomy movement, innovative technologies are being paired with affordable, high-quality equipment so a new generation of amateur astronomers can see the heavens like never before. The result is an emerging cultural and scientific shift that's exposing fresh audiences to stargazing and unlocking groundbreaking examples of citizen science.

Powerful commercial digital telescopes now allow stargazers without prior experience a chance to observe deep-sky objects from their back gardens, even in light-polluted skies. Meanwhile, innovative image-processing techniques and modern connectivity provide new ways to share and enjoy stunning views of celestial wonders on social media. And anyone can now make meaningful discoveries.

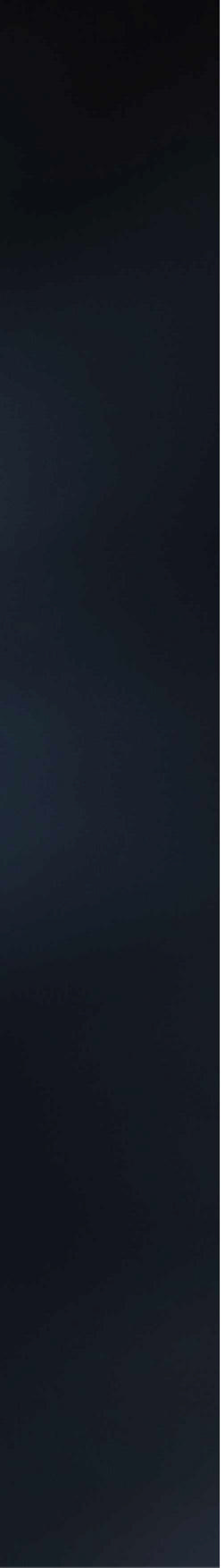
Amateur astronomers have long played a vital role in advancing research, but today's technology, including easy-to-use software and precision pointing abilities, lets citizen scientists contribute high-quality data in ways not previously possible. For example, recent observations by citizen astronomers have refined our knowledge of a number of asteroids' sizes and shapes, and helped with the study of targets to be visited by NASA's Lucy probe. Meanwhile, exoplanet observations from amateurs are helping astronomers to refine transit timings.

In a testament to their important contributions, scientific journal articles increasingly bear the names of citizen scientists as co-authors.

Scientists with NASA, ESA and other research groups keep a close eye on near-Earth objects (NEOs). Their planetary defence efforts might sound like science fiction, but the threat of an asteroid impact is real. By watching asteroid occultations and close flybys, distributed networks of stargazers around the world are adding impactful observations of NEOs to aid astronomers, who often don't have the resources to keep track of everything.

While we celebrate the technologies that launch tourists to space, it's worth remembering that similar advances are opening up the Universe to everyone else. In our present age, it's possible for us all to have access to the cosmos in a way that's both fun and meaningful — no rockets necessary.

KIKI LJUNG/FOLIO



Astronomy Photographer of the Year

BBC Sky at Night Magazine proudly reveals the 2021 winners of the world's biggest astrophotography competition

Every year, the Astronomy Photographer of the Year awards calls on astronomers around the world to submit the best images of the Universe they have taken over the previous year. In 2021, over 4,500 entries were submitted from over 75 countries, featuring everything from chance images that captured a meteor at the right time, to distant galaxies that took weeks of planning and capturing. The judges had a tough time deciding which of these spectacular images deserved the top prize of £10,000 but after hours of deliberation, their top picks for the 2021 competition can be revealed. You can see the winning images for yourself at the National Maritime Museum in Greenwich, London from 18 September. Visit **www.rmg.co.uk/astrophoto** for details.

MORE ONLINE
A gallery of these and more stunning images from the 2021 competition

FREE 2022 CALENDAR

Don't miss the December issue of *BBC Sky at Night Magazine*, which comes with a free 2022 calendar featuring the top images from the Astronomy Photographer of the Year 2021 competition. The calendar also lists all the unmissable astronomical events to observe in the night sky in the upcoming year. It goes on sale on 18 November 2021.

◁ Overall winner and Our Sun winner

The Golden Ring

Shuchang Dong (China)

Location: Ali, Tibet, China. 21 June 2020

Equipment: Fujifilm XT-4 camera. Sun: 386mm f/10 lens, ISO 160, 1/2000-second exposure. Moving cloud: ND1000 filter, 386mm f/16 lens, ISO 160, 1-second exposure

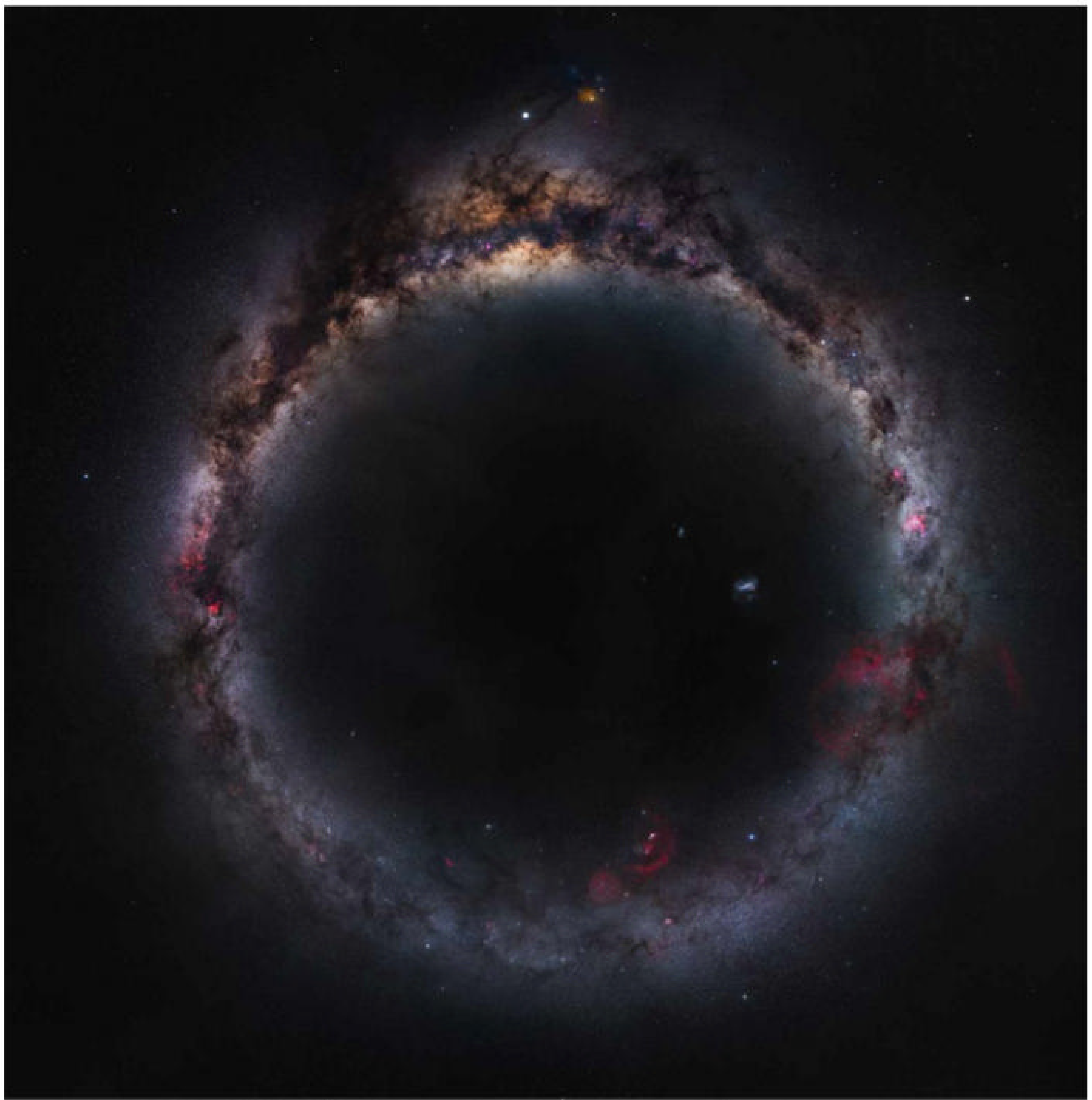
Judges verdict: "Solar eclipses have been capturing the interest of humans across the world for thousands of years. This image demonstrates both the beauty and simplicity of an eclipse, but also the science behind this astronomical event. Our Sun can still be seen as a ring circling the Moon as it passes in front of the solar disc, and mountains on the lunar surface can be seen hiding some of this light on the lower right-hand portion of the image. This is a stunning achievement!" **– Emily Drabek-Maunder** ▸

△ Aurorae
Polar Lights Dance
Dmitrii Rybalka (Russia)
Location: Approach to the Kara Strait, Russia. 30 November 2020
Equipment: Sony ILCE-7M3 camera, 28mm f/2.8 lens. ISO 100, 25-second exposure

Judges verdict: "How challenging it must have been to take this photo. The image is taken from the deck of a moving craft. How hard can it get! This is a great achievement and demonstrates fantastic opportunism." **– Alan Sparrow**

Galaxies ▷
The Milky Ring
Zhong Wu (China)
Location: Sichuan and Qinghai, China; Lake Pukaki, New Zealand. January–February 2020 and August 2020–January 2021
Equipment: Nikon D810a camera, 40mm f/1.4 lens. ISO 8000, 1,000x 6-second exposures

Judges verdict: "This cosmic circle is one of the most breathtaking entries we saw this year. The balance of colours, from the glowing upper half of the ring to the darker, moodier bottom half, seems to encompass a whole range of majesty and beauty. The dedication of the photographer, who took almost two years to piece this picture together, must be applauded too." **– Imad Ahmed**



Planets, Comets and Asteroids ▷

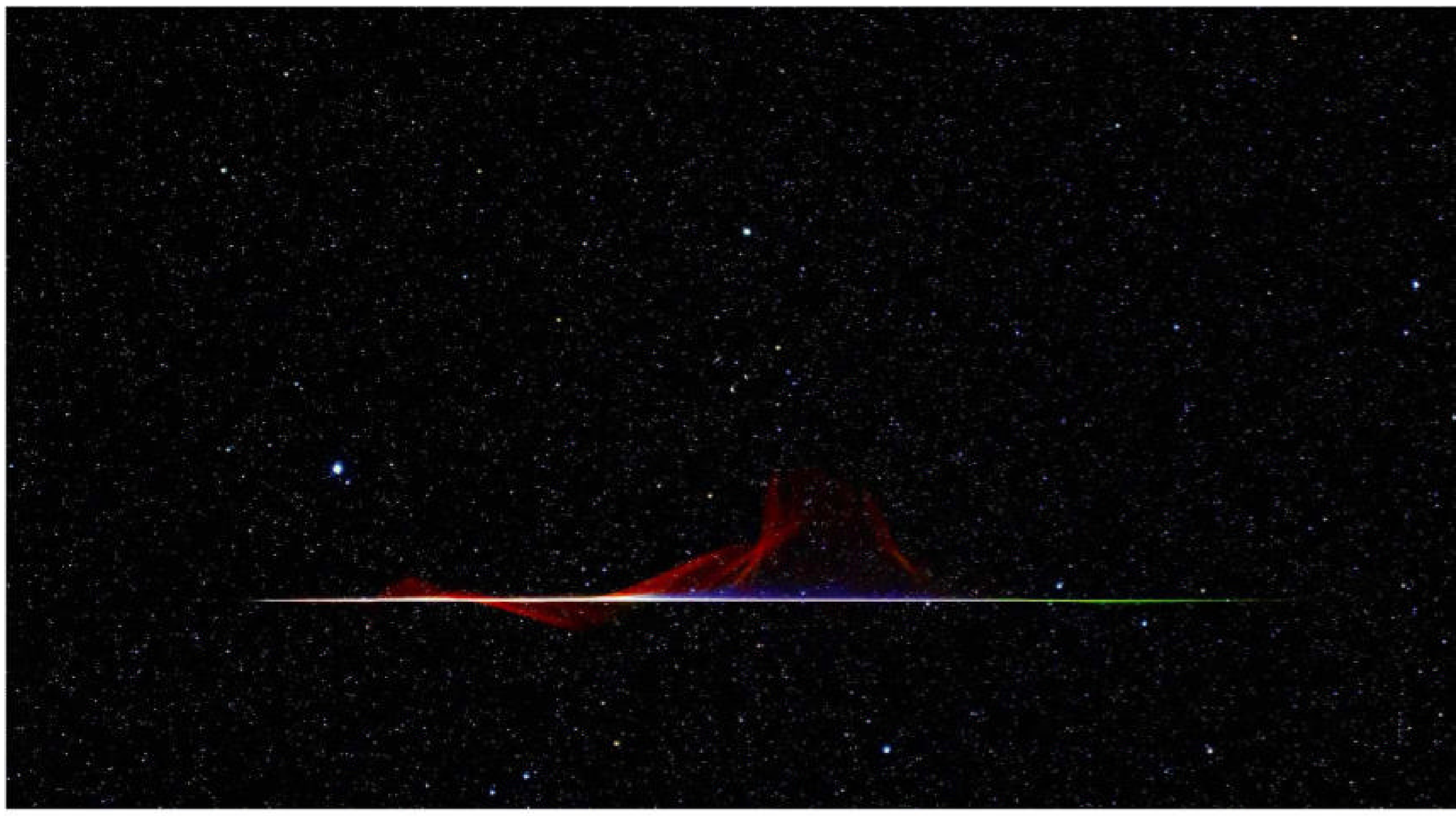
A Colourful Quadrantid Meteor

Frank Kuszaj (USA)

Location: Cook Station, Missouri, USA. 19 January 2021

Equipment: Sony a7R III camera, Sky-Watcher Star Adventurer star tracker, 70mm f/2.8 lens. ISO 3200, 1-minute exposure

Judges verdict: "A stinging, searing, lightsaber-esque image as the Quadrantid meteor pierces the atmosphere, with the spectrum appearing to explode as it goes. There is a real perception of incredible speed captured in the image."
– Jon Culshaw



▽ Our Moon

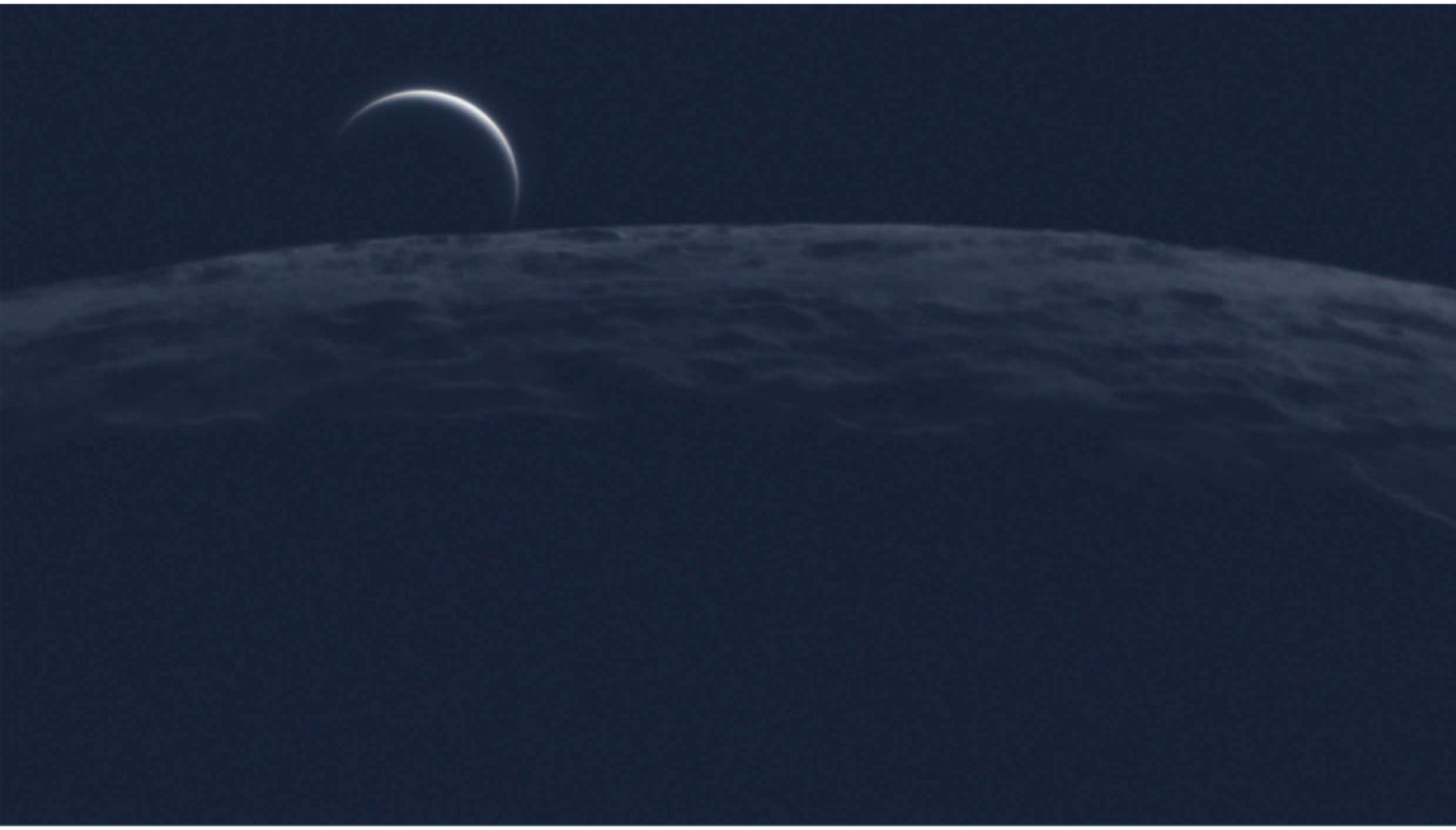
Beyond the Limb

Nicolas Lefaudeux (France)

Location: Forges-les-Bains, Île-de-France, France. 19 June 2020

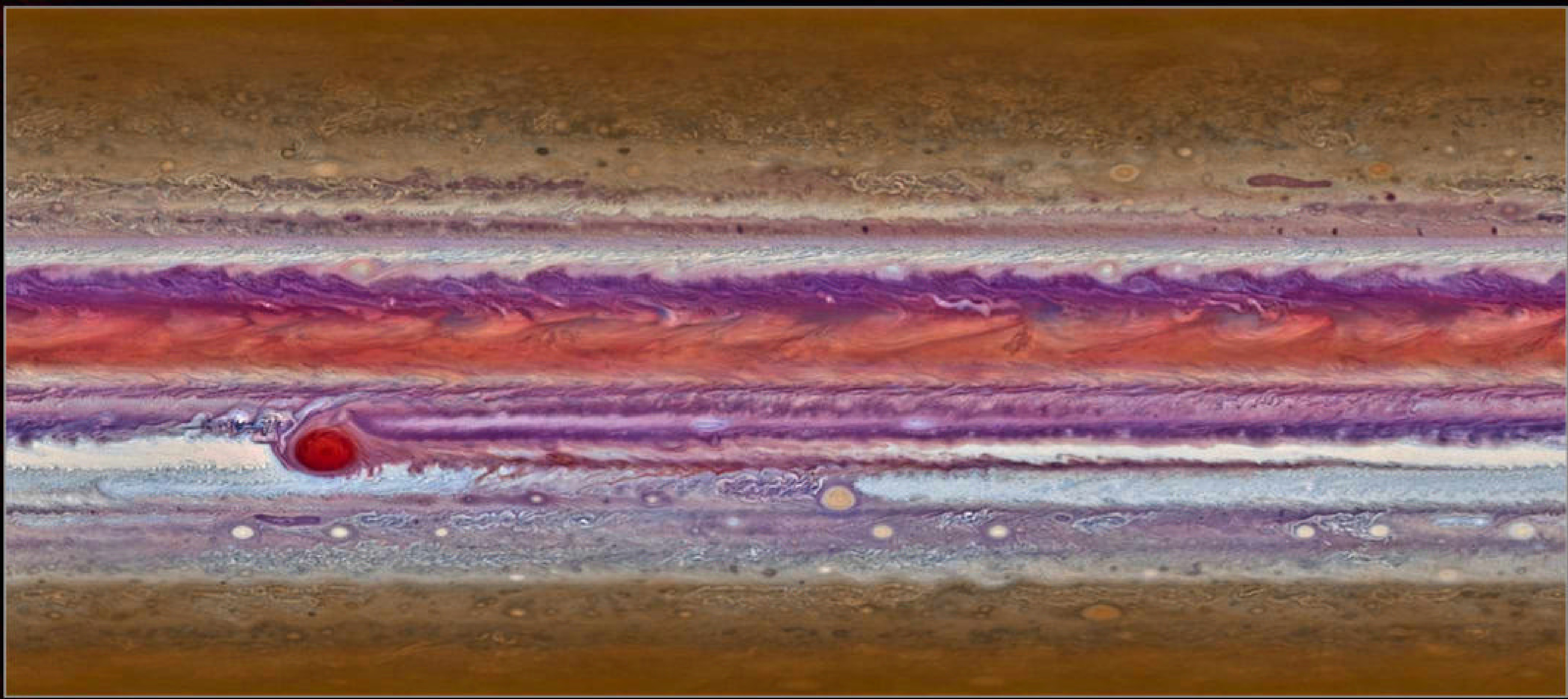
Equipment: Celestron C11 2,800mm telescope at f/10, iOptron iEQ30 mount, Basler acA2500-14gc camera. Occultation: 1x 2.5-millisecond exposures; Venus: 50x 2.5-millisecond exposures; Moon: 200x 15-millisecond exposures

Judges verdict: "I love how this image transports us. It almost appears as if we are standing on the surface of the Moon itself, looking into the rocky horizon. The dull surface of the Moon contrasts so well with the glowing planet. I enjoyed the inversion that this picture offers too – it is Venus that is the crescent here, and not the Moon." **– Imad Ahmed** ▸



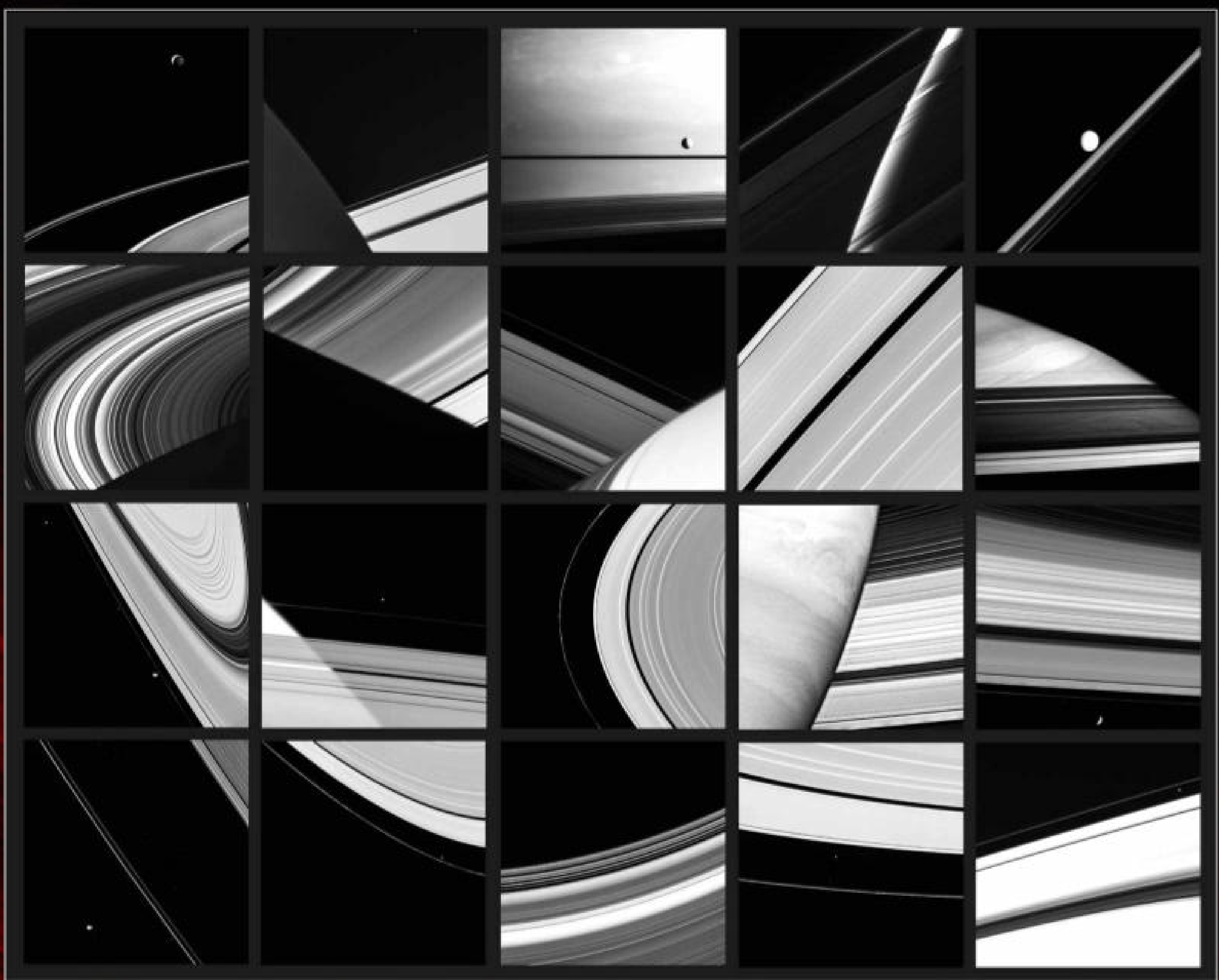
The Annie Maunder Prize for Image Innovation

This prize asks entrants to dive into the wealth of data available from professional telescopes, and put their own spin on the images to create new works of art



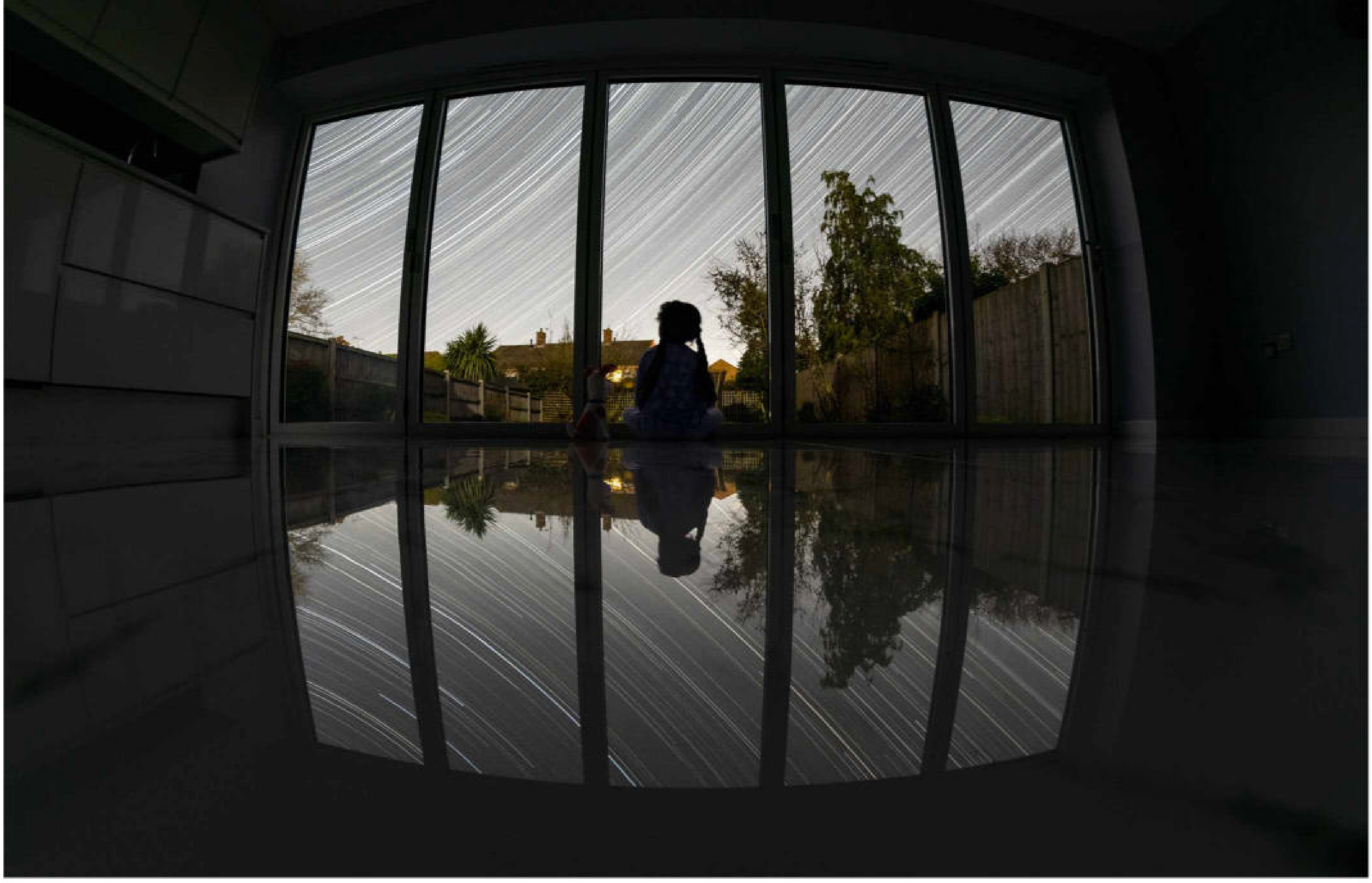
△ **Another Cloudy Day on Jupiter**
Sergio Díaz Ruiz (Spain)
Data Source: Hubble Space Telescope WFC3 (Wide Field Camera 3)/UVIS (Ultraviolet-Visible), (26–27 June 2019), FQ889, F631N, F502N, F395N, F467M, F658N, F275W, F343N channels, NASA/ESA HST Space Telescope, OPAL program (PI: Amy Simon, GO13937)

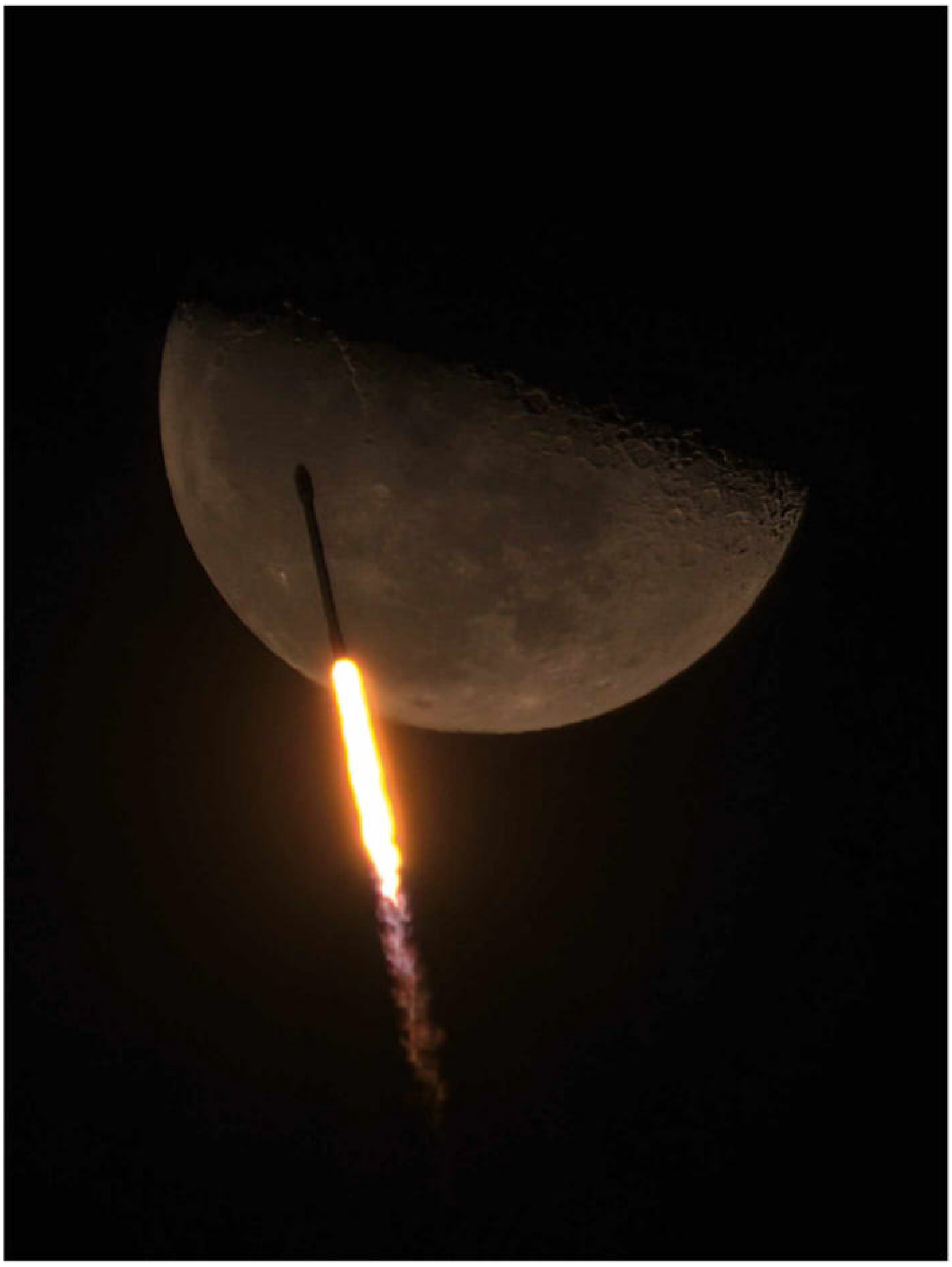
Judges verdict: "The gradient colours captured here are almost reminiscent of glimmering mineral samples. Precious, marbled and undulating, they're utterly enchanting." **– Sue Prichard**



◁ **Celestial Fracture**
Leonardo Di Maggio (UK)
Data Source: Cassini wide-angle camera (September 2004–October 2007), visible light channel, NASA/JPL/Space Science Institute

Judges verdict: "This image looks so incredibly different from how we normally see Saturn, the jewel of the Solar System. From spheres and rings to jagged edges and jarring curves, these close-up views of Saturn and its moons highlight the planet in new and innovate ways."
– Emily Drabek-Maunder





△ People and Space
Lockdown
Deepal Ratnayaka (UK)
Location: Windsor, Berkshire, UK. 20–21 January 2021
Equipment: Sony ILCE-6600 camera, 8mm f/4 lens. Foreground: ISO 1600, 8-second exposure; Sky: ISO 1000, 844x 30-second exposures

Judges verdict: "I love this picture taken during the lockdown. Astronomy photography clearly has its challenges but this photographer has embraced these to produce this fabulous picture of his daughter and the stars taken over several sittings. Brilliant."
– Alan Sparrow

◁ The Manju Mehrotra Family Trust Prize for Best Newcomer
Falcon 9 Soars Past the Moon
Paul Eckhardt (USA)
Location: Titusville, Florida, USA. 4 February 2021
Equipment: Sony ILCE-6500 camera, 210mm f/8 lens. ISO 400, 1/350-second exposure

Judges verdict: "This image stands out from many astrophotos and images of spacecraft (mostly ISS) in lunar transit. The right target, the right moment, the right composition – these three aspects make this photo the best. It couldn't be planned, this photo results from good situation awareness by a talented photographer." **– László Francsics** ▸

△ Stars and Nebulae

California Dreamin' NGC 1499

Terry Hancock (UK)

Location: Whitewater, Colorado, USA. 16–31 January, 6 and 28 February, 2 March 2021

Equipment: Takahashi FSQ-130 telescope at f/5, Chroma narrowband filters, Paramount ME mount, QHY600M camera. L-RGB-Ha-SII-OIII composite; 16.1-hours total exposure

Judges verdict: "I absolutely love this image of Thackeray's globules surrounded by the stunning colours of the California Nebula, appearing as if they were gracefully floating within it." **– Melissa Brobby**

▽ Young Competition

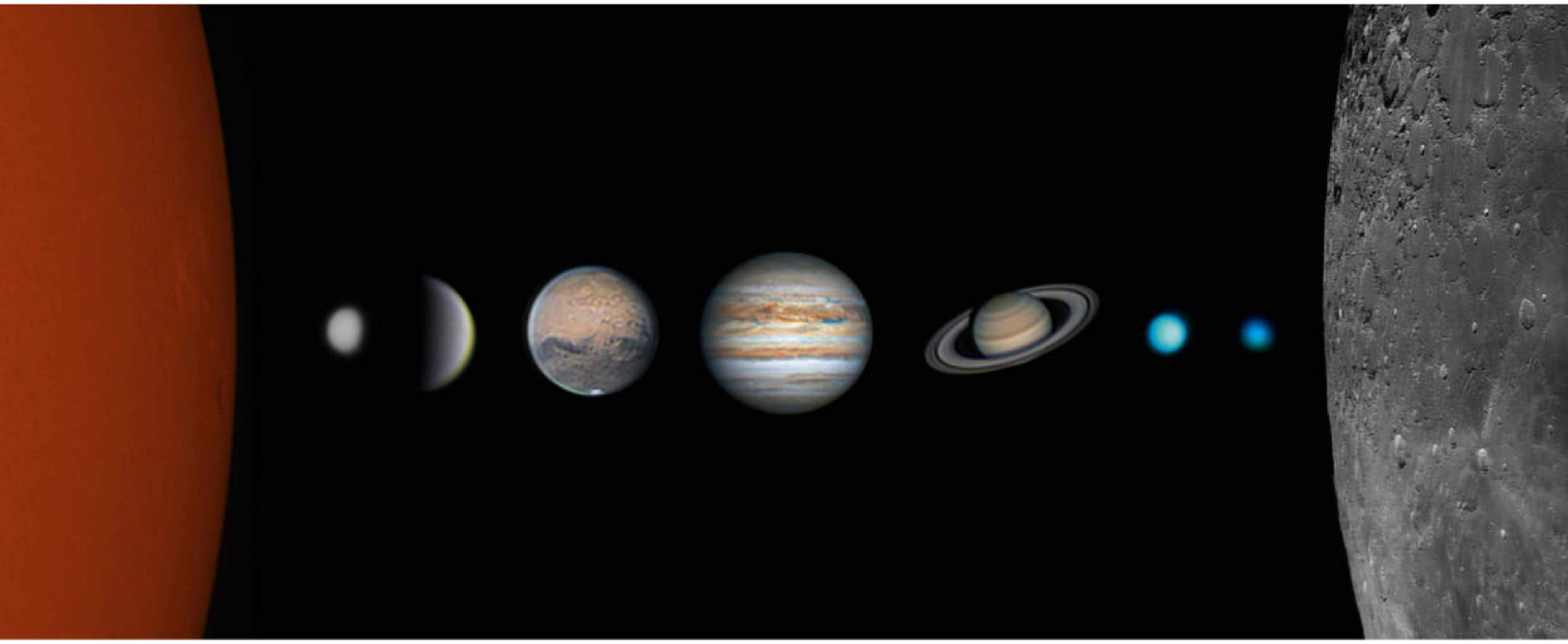
Family Photo of the Solar System

Zhipu Wang, aged 15 (China)

Location: Yongtai, Fujian, China. 14 August 2020 – 21 January 2021

Equipment: Celestron C8 SCT telescope, UV/IR cut filter, Celestron AVX mount, ZWO ASI224MC camera. Sun: 200mm f/10 lens, Baader filter, 750x 18-millisecond exposures; Moon: 2x Barlow, 200mm f/10 lens, 2,250x 10-millisecond exposures; Planets: 2x Barlow, 4,000mm f/20 lens, multiple 7–46-millisecond exposures

Judges verdict: "As a planetary scientist I applaud the work that has gone into creating this photo. I really like the composition with the Moon on the right-hand side too." **– Sheila Kanani**



△ Skyscapes

Luna Dunes

Jeffrey Lovelace (USA)

Location: Death Valley National Park, California, USA. 25 February 2020

Equipment: Sony ILCE-7RM4 camera. Sand and sky: 70mm f/8 lens, ISO 400, Sand: 30-second exposure, Sky: 1-second exposure; Moon: 200mm f/2.8 lens, ISO 100, Moon face: 2.5-second exposure, Moon edge: 1/100-second exposure

Judges verdict: "This is a wonderful composition. The colour grading is amazing. Great care has been taken in seamlessly combining all the elements of the scene. A truly spectacular and very well-balanced image." **– Yuri Beletsky**

THE JUDGES

Imad Ahmed
Director of the New Crescent, which celebrates the relationship between Islam and astronomy

Yuri Beletsky
Astro imager and astronomer at Chile's Las Campanas Observatory

Melissa Brobby
Journalist and Social Media Officer for the Institute of Physics

Jon Culshaw
Comedian, impersonator and regular guest on *The Sky at Night*

Emily Drabek-Maunder
Senior Manager of Public Astronomy at Royal Museums Greenwich

László Francsics
Overall winner, Astronomy Photographer of the Year, 2019

Sheila Kanani
Education, Outreach and Diversity officer for the Royal Astronomical Society

Steve Marsh
Art Editor of *BBC Sky at Night Magazine*

Sue Prichard
Senior Curator of Arts at the Royal Museums Greenwich

Alan Sparrow
Director of Fleet Street's Finest and Chair of the UK Picture Editors' Guild

URBAN STARGAZING

Astronomy under light-polluted skies

Astronomer **Will Gater** guides you through the possibilities of stargazing from more brightly-lit locations

While the world of astronomy regularly trades on visions of dark expanses swarming with stars and the river-like Milky Way arcing over remote landscapes, the reality for most of us is that stargazing occurs under, or close to, the bright lights of towns and cities. From these locations contemplating the Universe can be challenging, as wasted artificial light fills the sky with a diffuse, nocturnal glow.

Although the near-fantastical vistas of Instagram and space documentaries might be lightyears from our 'every night' experience, there's still an enormous diversity of engaging targets for an astronomer to enjoy under urban and suburban night skies. In this article we highlight a few key examples – and offer some tips on how to get started – to show that you don't need to live under the darkest skies to connect with the wonders of the cosmos above. ▸

Will Gater is an astronomy journalist and science presenter. His book, *The Mysteries of the Universe*, is published by DK

WILL GATER

Even in light-polluted urban areas, there's a wide selection of night-sky targets waiting to be discovered

BBC Sky at Night Magazine

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To learn more about capturing the heavens from urban environments, sign up for our Masterclass series on astrophotography at **skyatnightmagazine.com/virtual-events**

Atmospheric 'transparency' is essentially a measure of how clear a clear night sky is

Getting transparent about light pollution

A key factor that influences how bad the effects of light pollution are is the haziness of the sky

If you live in an urban or suburban area, the fact that badly directed and excessive artificial light obscures the stars over our towns and cities isn't going to be news to you. But if you're just getting into stargazing, it can be useful to explore exactly how this light pollution affects certain kinds of astronomical observing – not least because this can help you prepare for nights when the effects are lessened somewhat. Clouds, of course, can spoil an observing session no matter where you're observing, but there's another atmospheric phenomenon that all town-based stargazers will know is hugely important to the clarity of their views: astronomers call it the 'transparency'.

Atmospheric transparency is a measure of how clear your clear skies are. Hazes or pollution (suspended in the air) can create milky, murky skies and what can be called 'poor' transparency. Conversely, crystal-clear nights free of these intrusions are said to possess 'good' transparency.

The reason why transparency is important to monitor when observing the night sky from urban areas is that hazy skies can elevate the problems associated with light pollution: the particles in the air scatter the glow from below and the result is a brighter night sky, where it's harder to see fainter stars. Paying attention to transparency levels can help you plan observing sessions. If you can see that the sky is milky and the skyglow is enhanced you can focus your attention on brighter targets like the Moon and planets. When the transparency is good you can go after fainter objects like star clusters.

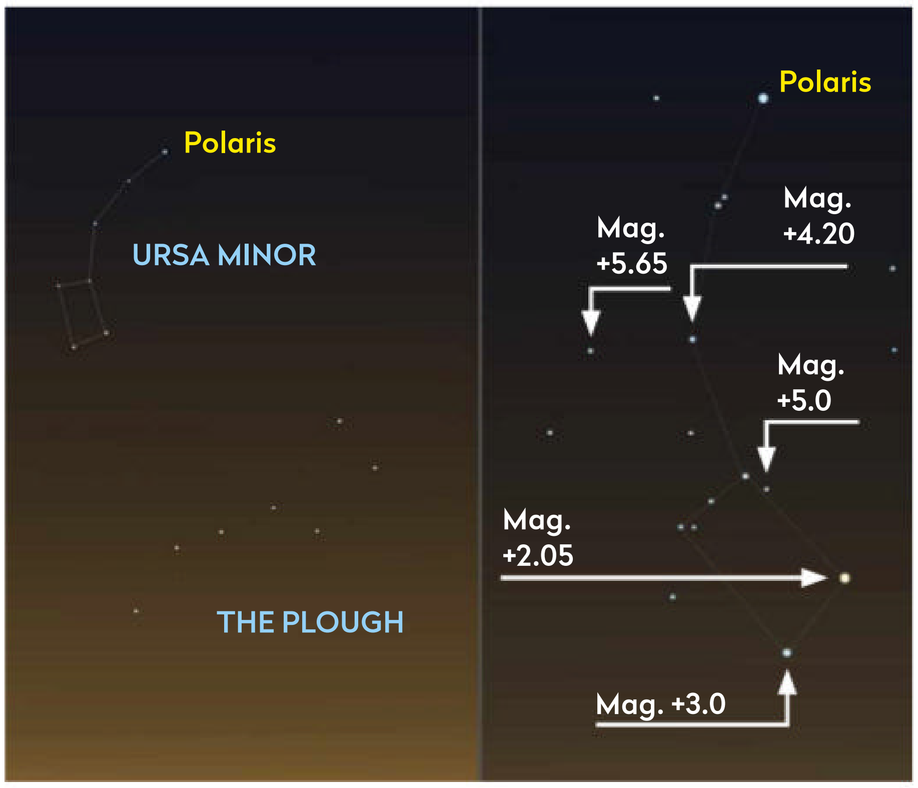
Know your limits

Working out the faintest stars you can see will help you get your bearings in the night sky

When you begin exploring the night sky from a town or city it's a great idea to have a star atlas, a planetarium computer program or an app to help you navigate your way around the stars. However, before you open one of these up, it's well worth doing a quick exercise to establish what you can actually see under your local night sky.

Essentially, you want to find out what the faintest stars are that you can discern – what astronomers call the 'naked-eye limiting magnitude' or NELM. To do this you can use a constellation that's always visible at night in the UK, like Ursa Minor, the Little Bear. It's a fairly easy pattern to find as the tip of the Little Bear's tail is the bright star Polaris, the North Star. Using the chart here (right), a star chart or an app, look carefully to see what brightness, or magnitude, the dimmest star you can perceive is – remember, the lower the number, the brighter the star. For suburban locations under fairly average conditions, this might be around mag. +3.0 to +4.0.

Many planetarium programs and apps have tools that have the ability to limit the magnitude of the stars displayed. So if you set the magnitude at the level of your local NELM, what's shown on screen will be only the stars you can see from your observing site. In turn, this can make star-hopping, or jumping from star to star to locate fainter objects, much easier.



▲ Choose a constellation that's always visible, like Ursa Minor, to work out the magnitude of the dimmest star you can see

WILL GATER X 4, OVERSNAP/ISTOCK/GETTY IMAGES

Metropolitan Moon imaging

The bright Moon cuts through skyglow, making it a great target for urban astrophotography

▲ A lens with a long focal length can make the Moon appear large as it rises over a city, like in this view of London's skyline

▲ By using a high frame rate camera combined with a telescope and laptop you can obtain stunning images of the lunar surface

NIGHTSCAPES

Dramatic city horizons and striking buildings make for great foregrounds in nightscape photos containing the Moon. What's more, this kind of image – perhaps showing a Moonrise, lunar halo or total lunar eclipse – can be achieved with just a smartphone camera.

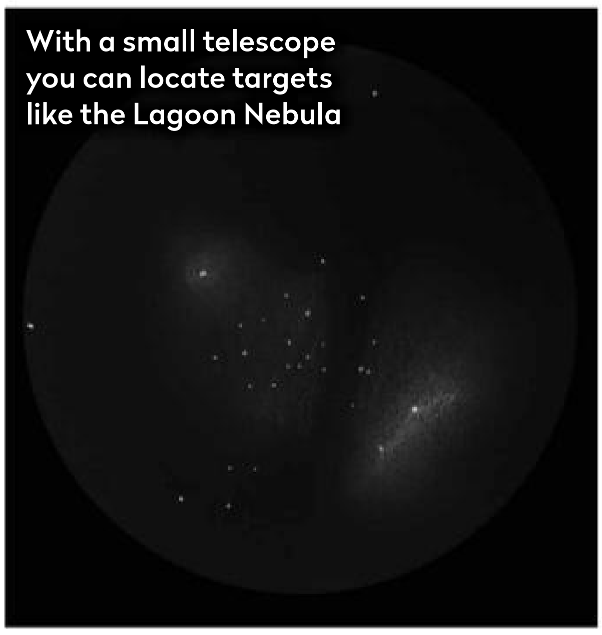
With a basic DSLR or bridge camera and a longer lens you'll be able to push things further, capturing more detail on the lunar disc. Very long focal-length lenses – above, say, 300mm – can allow you to get an eye-catching compressed depth-of-field effect, making a full Moon appear huge as it rises up over a distant urban skyline.

IMAGING WITH A HIGH FRAME RATE CAMERA

Lunar imaging with a high frame rate device, like a webcam or a dedicated astronomical camera, can be a hugely rewarding pastime and is one of the few types of astrophotography that can be carried out without any substantial loss in quality due to skyglow. To do it you'll need a small telescope, a camera and a laptop to receive the data. High frame rate imaging works by the camera taking a video of the view through the telescope. Software like the free RegiStax then selects the best frames to stack into one image that is then sharpened and processed further. The results are far superior to what you can achieve with a single shot, from something like a DSLR.

Make the most of your telescope or binoculars

Not all deep-sky sights are out of reach from brightly-lit towns and cities



With a small telescope you can locate targets like the Lagoon Nebula

While many fainter objects will be largely lost or hard to find in the skyglow from suburban locations, a small telescope or a good pair of binoculars will nonetheless show you a respectable number of brighter deep-sky targets including star clusters, bright planetary nebulae, and summer and winter showpieces like the Orion Nebula and the Lagoon Nebula. There are also a few things you can do to reveal these wonders more clearly.

Firstly, use a light pollution filter tailored to visual observing as these are specifically designed to suppress the glow from artificial light.

Consider your observing position, too. For example, never observe from inside a building with the door or window open – as the escaping warm air will create air currents and cause the view to shimmer; this is most noticeable when viewing the Moon and planets, but applies to deep-sky observing too. Try not to view targets that are directly over rooftops, or above hot air vents, as that will avoid similar issues.

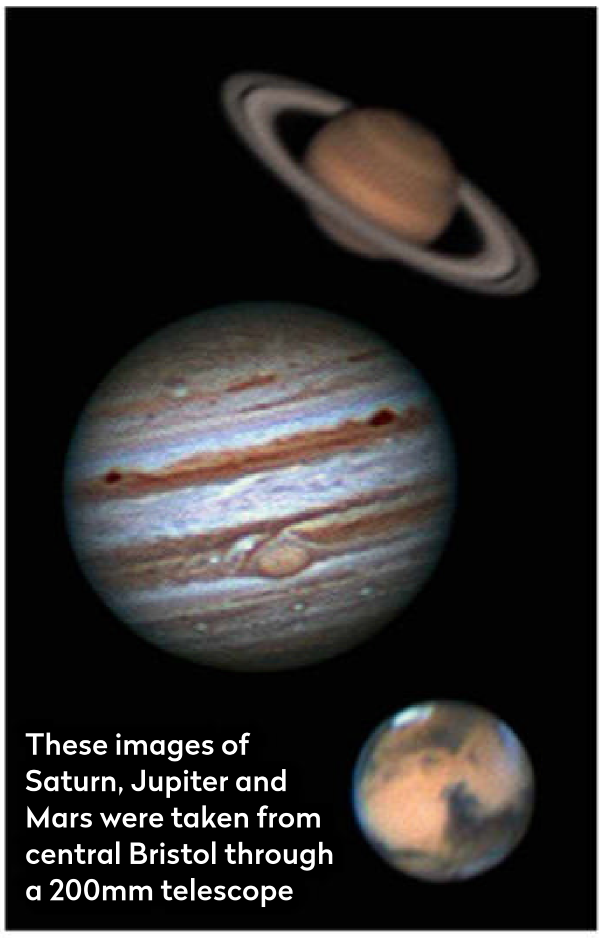
Finally, just as one would from a darker location, allow your eyes at least 30 minutes to adapt to what darkness there is – and keep any artificial lights out of your direct line of sight if you can. ▸

Picking out the planets

These objects can be spied from even heavily light-polluted cities

The planets are one of the few astronomical target groups that are pretty much completely unaffected by the problems of light pollution. While you'll probably struggle to glimpse distant Uranus with the naked eye, like you can at dark-sky sites, and telescopic observations of some of the fainter moons of Saturn might be a little harder to come by, for the most part you can get great views of the other worlds in our Solar System with a small telescope even from brightly-lit cities. What's more, high-resolution planetary imaging can be conducted with great success under light-polluted skies – some of the world's best astrophotographers in this field work from homes in urban and suburban locations.

Jupiter, with its cloud bands, and Saturn with its rings are of course superb targets for even small-aperture instruments. Bright Mars, at opposition, and the crescent Venus also offer captivating views in larger aperture scopes – the latter needing a careful observing approach, ensuring the Sun is below the horizon before viewing starts. From suburban locations, with a 200–250mm aperture telescope, you can even get nice eyepiece views of the faint discs of Uranus and Neptune.

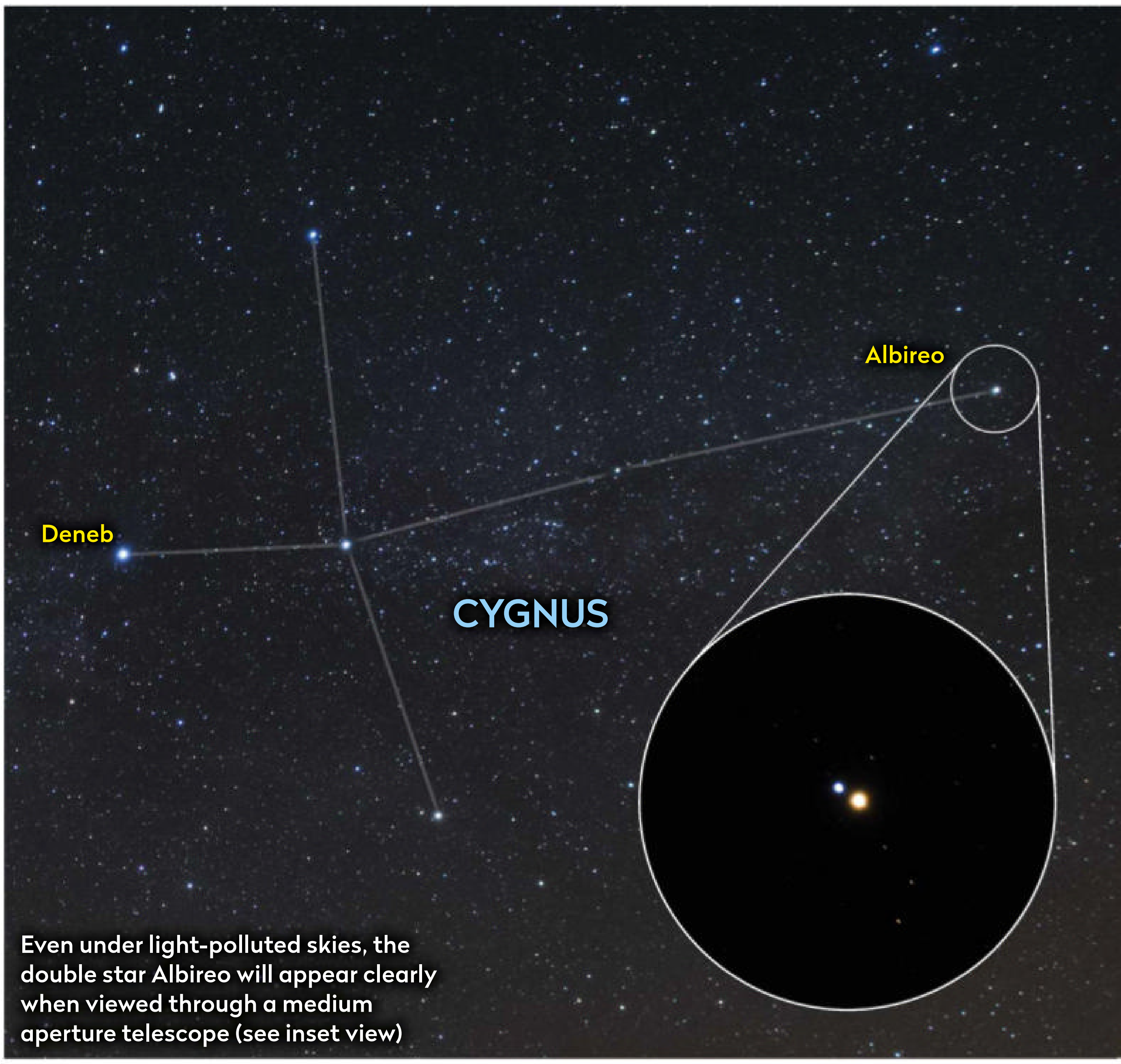

These images of Saturn, Jupiter and Mars were taken from central Bristol through a 200mm telescope

Subtleties in the stars

Double and variable stars can provide an interesting observing project

Among the stars that are able to poke through the light pollution in built-up areas you'll find some interesting targets for a small to medium aperture telescope. These include some of the brighter double and multiple-star systems, where two or more stars either appear close together or are, in fact, whirling together as a gravitationally-bound group through space. In the summer and autumn months, notable examples such as Albireo (Beta (β) Cygni) in Cygnus, and Epsilon (ε) Lyrae in Lyra, are comfortably within reach of a 150–200mm aperture telescope from sites with fairly bright night skies.

If you're interested in long-term observing projects with a telescope, you'll also find that some variable stars – stars whose brightness fluctuates – like Algol (Beta (β) Persei) in Perseus, often periodically glow strongly enough to be seen through moderate light pollution. Observing them and recording estimates of their magnitudes can be an interesting and rewarding exercise. If you're keen, you can even get involved with the scientific work of organisations such as the British Astronomical Association and the American Association of Variable Star Observers by submitting measurements to their variable star monitoring programs.



Even under light-polluted skies, the double star Albireo will appear clearly when viewed through a medium aperture telescope (see inset view)

STEVE MARSH, WILL GATER X 3

Displays of noctilucent clouds are easily visible from cities in the summer months

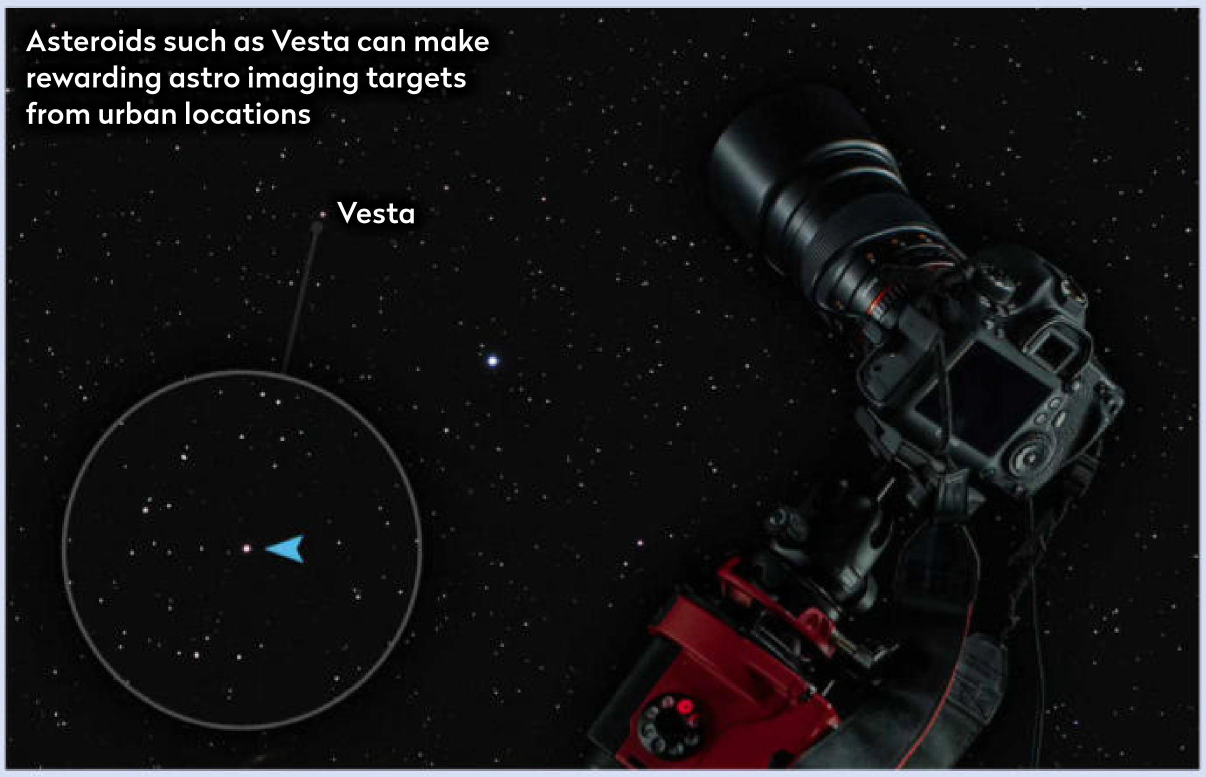
Ghostly glows on the horizon

Keep an eye to the north throughout the summer and you might spot a noctilucent cloud display

During summer in the UK, noctilucent – meaning 'night-shining' – clouds can appear on the northern horizon about an hour and a half after the Sun has set. Composed of ice crystals, these clouds form around 85km up in our atmosphere and shine because, at those heights, they're in sunlight. The brightest displays can be easily seen and photographed from light-polluted towns and cities against the twilight. Noctilucent clouds, or NLCs, have a characteristic blueish-white hue to them and so stand out quite clearly from regular high clouds, like cirrus, from urban spots. This is because when cirrus is being lit by light pollution it will usually have a slight orangey or greenish-white hue. Wisps of regular high cloud also tend to look quite dull when scattering skyglow, whereas bright NLCs really do look like they're glowing.

Snap an asteroid

Several of the brightest inhabitants of the asteroid belt are easy imaging targets from brightly-lit areas. We show you here how to shoot a large target like Vesta



Asteroids such as Vesta can make rewarding astro imaging targets from urban locations

TIMING IS KEY

To be in with a good chance of capturing Vesta on camera you'll want to image it when it's around 'opposition', ie when it's opposite the Sun in the night sky. Typically, objects are near their brightest at this time. *BBC Sky at Night Magazine*'s 'Sky Guide' regularly details asteroid oppositions.

GO TO GREAT (FOCAL) LENGTHS

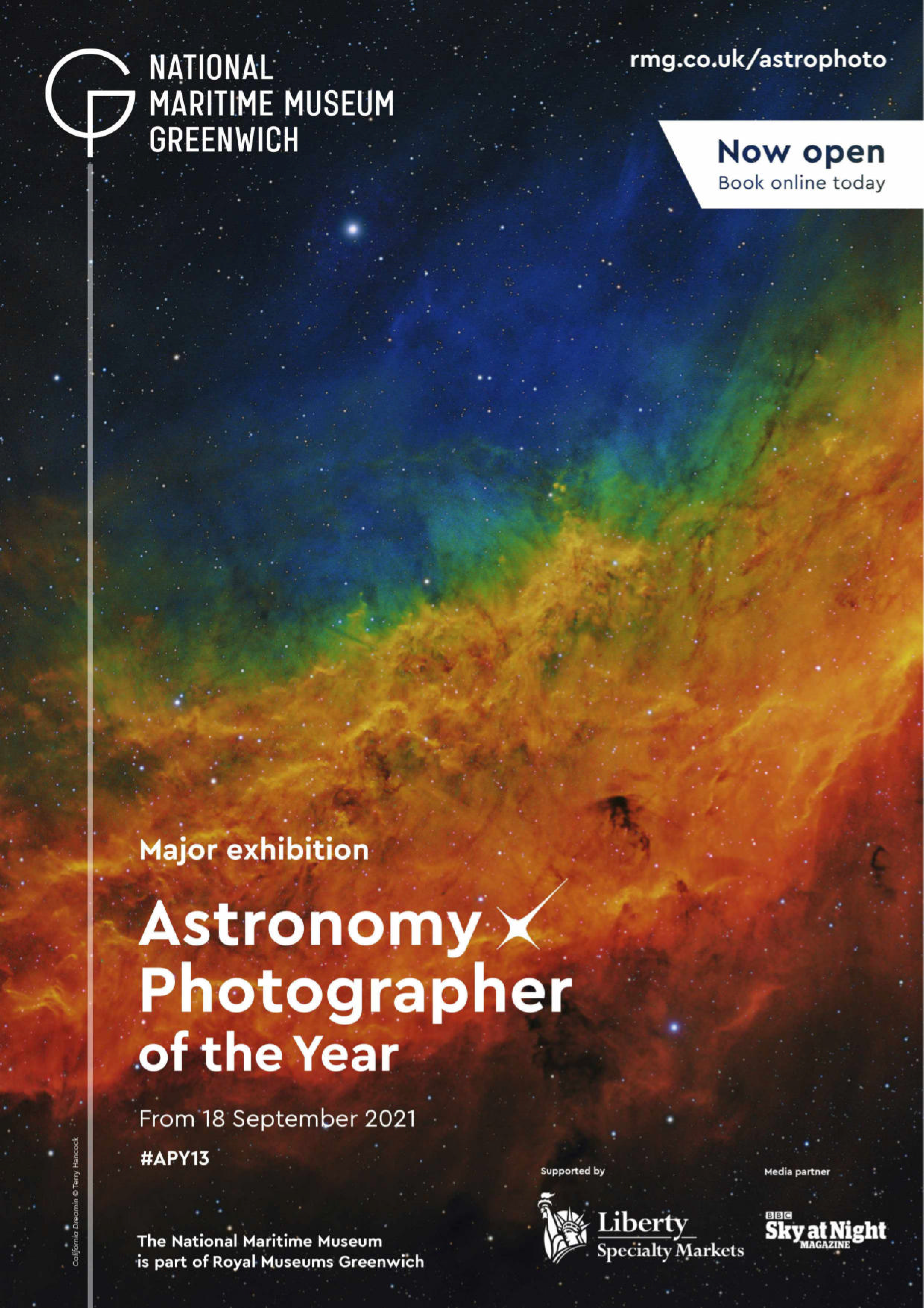
A basic tracking mount to carry your camera and a lens will help you take pin-sharp exposures of 30 seconds to a minute in length. Aim to use a lens of at least 50mm in focal length, and preferably longer, as this should be sufficient to pick out larger asteroids, such as Vesta.

PINPOINT IMAGING

Gather many exposures and stack them in software like DeepSkyStacker or similar to create a smoother image, where it's easier to discern the pinpoint light of an asteroid. If you don't have a tracking mount, use a static tripod and capture lots of exposures (a few seconds in duration) at a fairly high ISO setting.

REPEAT TO SEE VESTA MOVE

Once you've produced an image of the tiny spot of light that is Vesta among a star field, you can repeat the whole process again a few days later. Load the two images into an image editor and flick between them to watch Vesta moving against the background stars.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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

OCTOBER 2021

A RARE DOUBLE

View the shadows of Callisto and Ganymede crossing Jupiter at the same time!

DRACONIDS ON DISPLAY

A lower-rate meteor shower takes centre stage

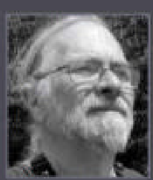
DISAPPEARING ACT

See the star Eta Leonis play hide and seek with the Moon

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Mercury at greatest western elongation
- Venus reaches greatest eastern elongation
- A thin Moon-spotting opportunity

Red light friendly

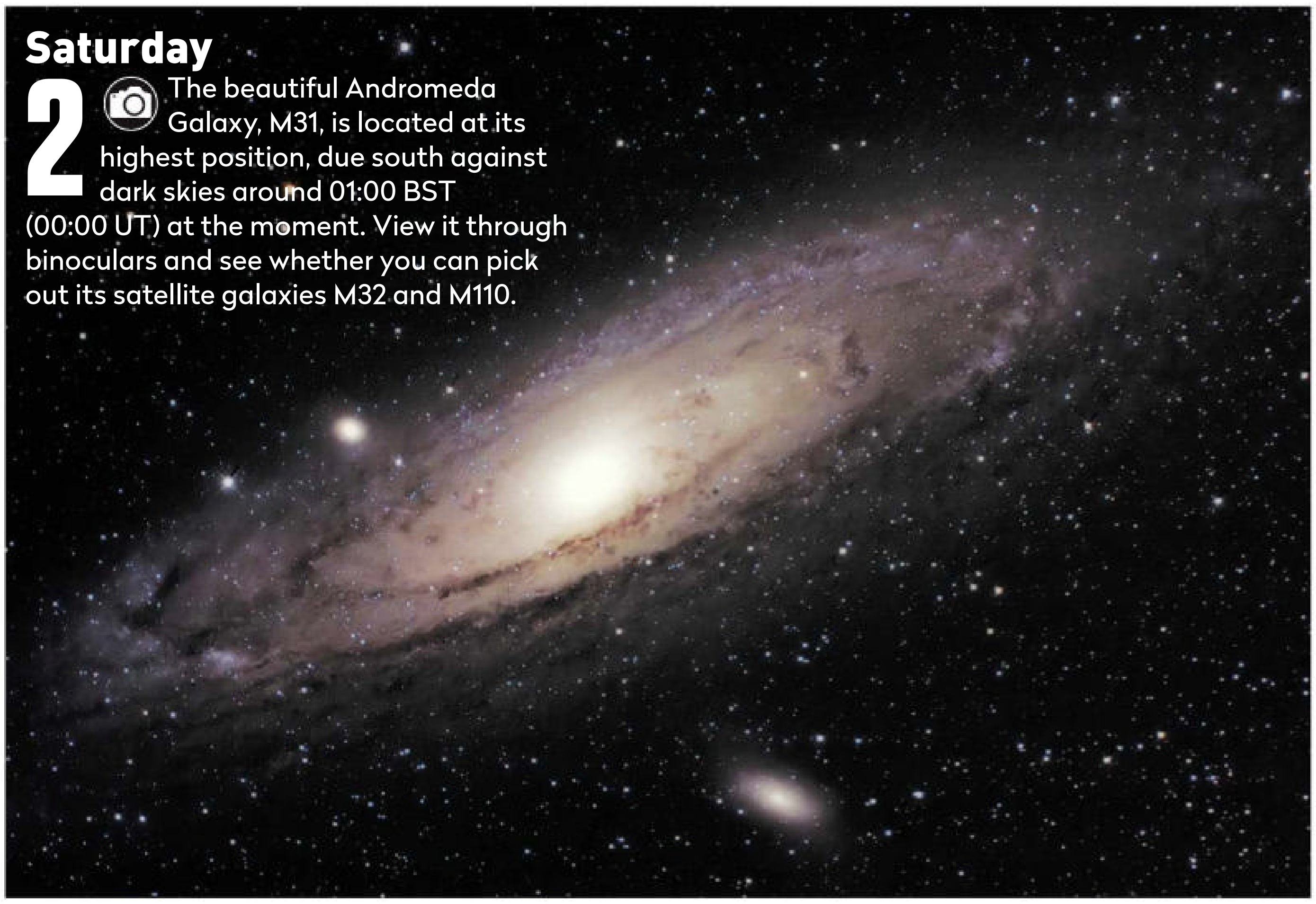
To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

OCTOBER HIGHLIGHTS

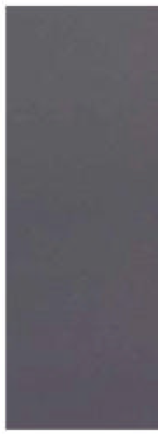
This month's stargazing and imaging at a glance



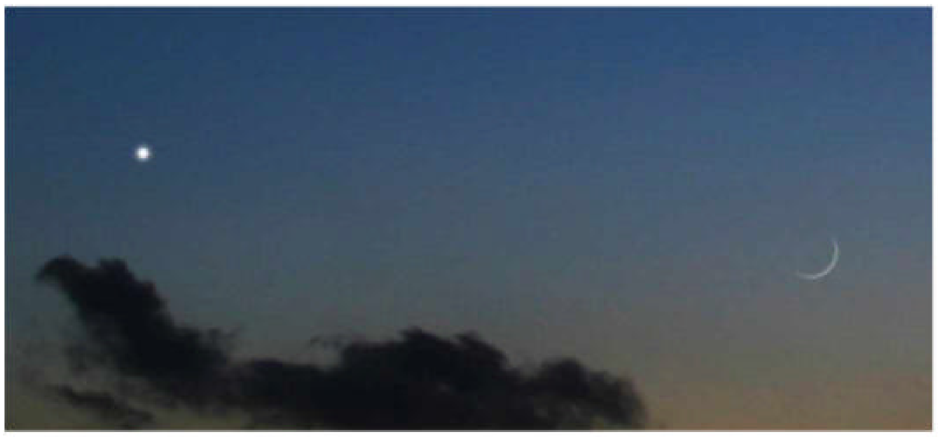
Saturday 2 The beautiful Andromeda Galaxy, M31, is located at its highest position, due south against dark skies around 01:00 BST (00:00 UT) at the moment. View it through binoculars and see whether you can pick out its satellite galaxies M32 and M110.

Sunday 3 This morning, mag. +3.5 Eta (η) Leonis will be occulted by a 13%-lit waning crescent Moon. Those in the far north will see the star pass close to the Moon's northern limb. Observe from 04:35–05:20 BST (03:35–04:20 UT).

Tuesday ▶ 5 Look towards the east from 06:00 BST (05:00 UT) and you might see a 1%-lit waning crescent Moon rising this morning. Optimally positioned, the Moon rises 100 minutes before the Sun.



Saturday ▶ 9 A 14%-lit waxing crescent Moon meets mag. –4.1 Venus this evening, appearing 2.1° apart. Look for the pair low above the southwest horizon shortly after sunset. Mag. +2.3 Dschubba (Delta (δ) Scorpii), sits 50 arcminutes northeast of Venus.



Sunday 10 The peak of the Southern Taurid meteor shower occurs today. Although it has a low peak ZHR of just five meteors per hour, the peak is broad and sometimes has slow bright trails.

Thursday 14 The now 67%-lit waxing gibbous Moon sits south of Saturn and Jupiter this evening, forming a triangle in Capricornus, the Sea Goat.

The clair-obscur effect known as the Eyes of Clavius is visible around 19:30 BST (18:30 UT).

Friday 15 The Jewelled Handle clair-obscur effect (a semicircle of light caused by the Moon's Jura mountains catching the light of a lunar dawn) is visible around midnight tonight, as the Moon approaches the southwest horizon, near mag. –2.5 Jupiter.

Thursday 21 The peak of the Orionids occurs, but it's marred by a Moon that's just-past full.

Jupiter's moons Callisto and Io transit the gas giant's disc together, starting at 00:30 BST (23:30 UT on 20 October). See page 46.

Monday 25 Mercury is at its greatest western elongation today, appearing separated from the Sun by 18.4° in the morning sky. Shining at mag. –0.5, Mercury rises nearly two hours before the Sun.

Family stargazing

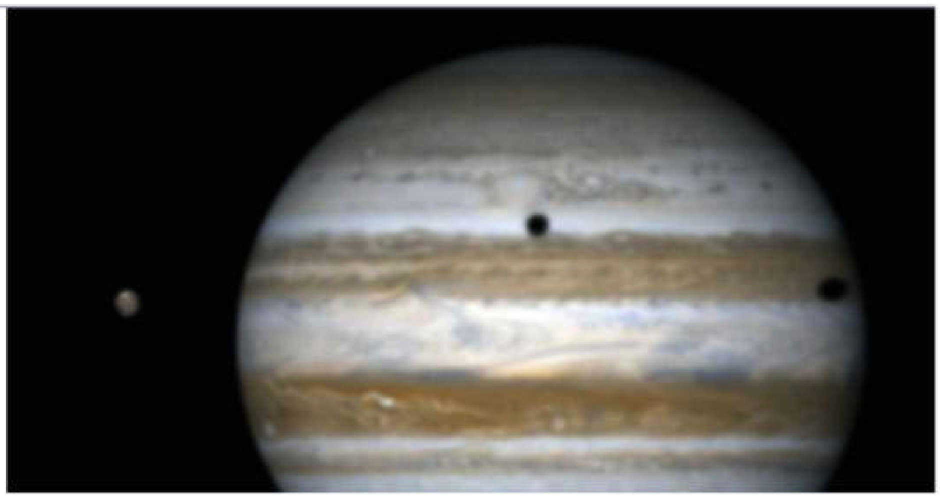
Jupiter is currently bright and well positioned, an easy naked-eye planet. It reaches its highest position due south at 10pm BST on 1 October, at 9pm BST on 15 October and 7pm UT on 31 October. This is a great planet to observe with a telescope. Point out its flattened globe, due to its rapid rotation, and the two dark stripes that run parallel to the equator. The four largest moons stand out well too and are easy for young eyes to see. Try for some of the moon shadow events listed in our calendar – especially the rare double shadow transit on 4 October. **www.bbc.co.uk/cbeebies/shows/stargazing**

Friday ▶ 29 Venus reaches greatest eastern elongation, appearing separated from the Sun by 47° in the evening sky. Despite this, Venus's position isn't optimal at present and this brilliant mag. –4.3 planet sets a little over 1.5 hours after the Sun.

PETE LAWRENCE X 6

Monday ▶

4 Today offers a rare chance to catch Ganymede and Callisto casting shadows on Jupiter at the same time. Callisto's shadow begins its transit from 18:00 BST (17:00 UT). Ganymede's shadow transit starts at 19:50 BST (18:50 UT). Turn to page 46 to find out more.



Thursday

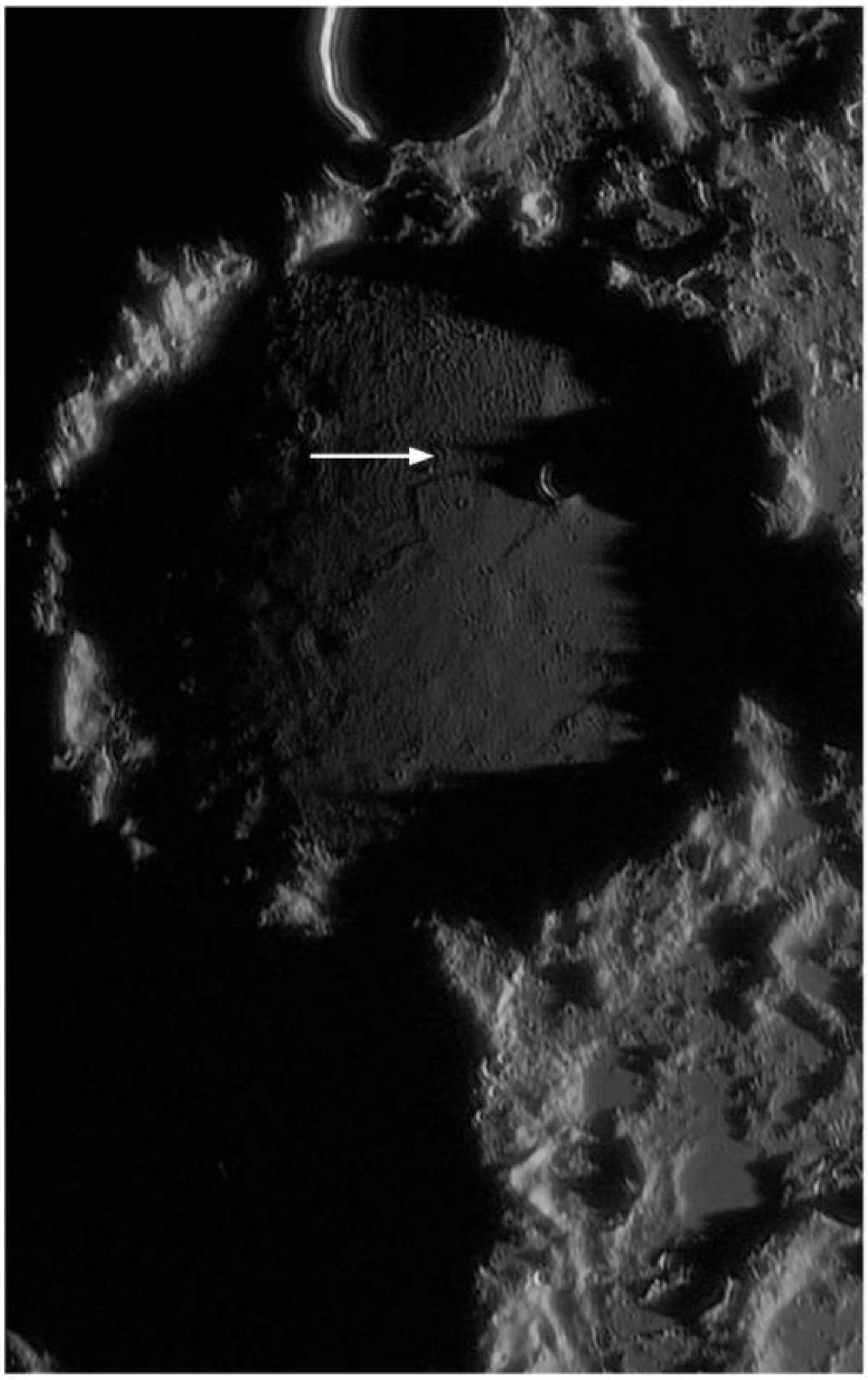
7 A thin 2%-lit waxing crescent Moon may be seen low above the west-southwest horizon shortly after sunset.

Friday

8 The peak of the Draconids occurs today. Although the meteor shower has a ZHR (zenithal hourly rate) of five meteors per hour, it has shown unexpected activity in recent years, with a ZHR of 150 over a four-hour period in 2018. See page 47 for more.

Wednesday ▶

13 An unusual clair-obscur effect occurs within lunar crater Ptolemaeus this evening. The shadows create a shape reminiscent of the Loch Ness Monster's head and neck. Look out for Nessie around 19:45 BST (18:45 UT).



Thursday

28 Tonight's last quarter Moon rises around 23:30 BST (22:30 UT). Once it's up see if you can spot the Beehive Cluster 2.7° to the south-southwest. Binoculars should fit both objects in the same field of view comfortably.

Sunday

31 British Summer Time ends this morning at 2am BST, when the clocks go back to 1am GMT (01:00 UT).

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

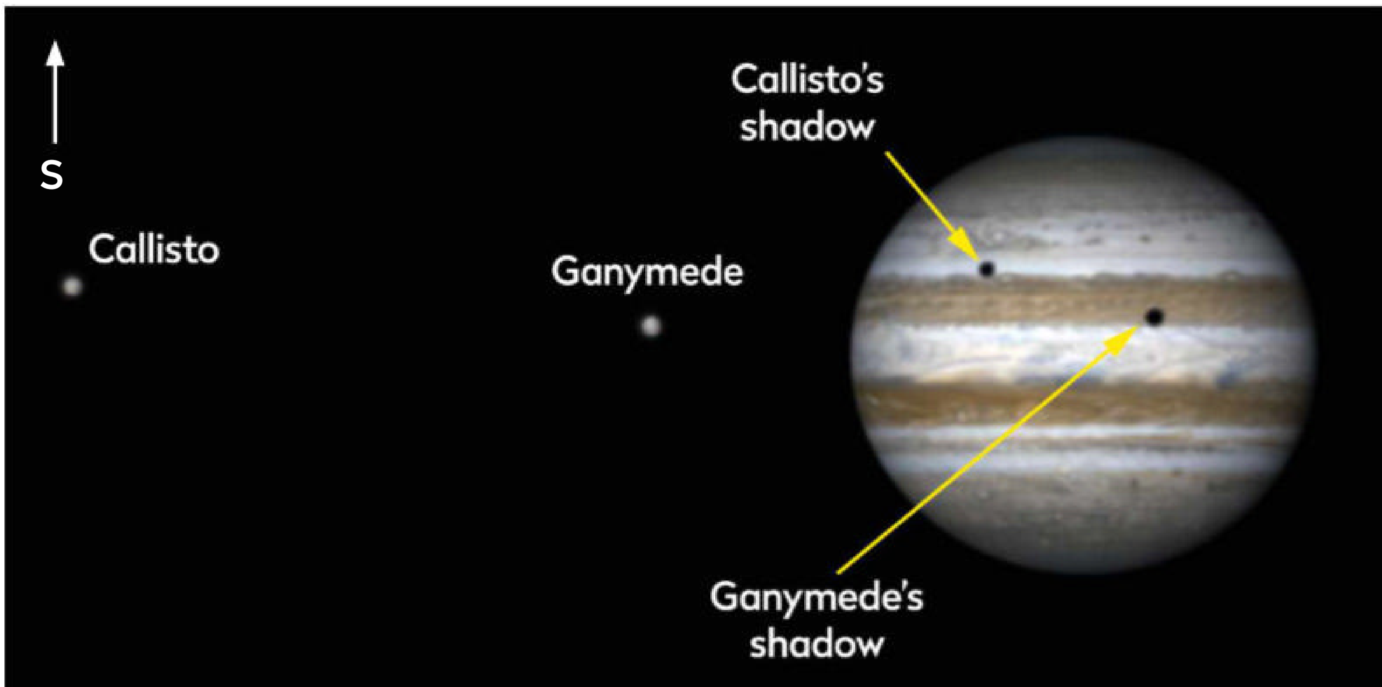
GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

JUPITER MOON EVENTS

BEST TIME TO SEE: Multiple events, dates and times as specified.



Catch the double shadow transit on 4 October at 20:53 BST (19:53 UT)

On Monday 4 October, there's a rare opportunity to see the shadows of Ganymede and Callisto in transit simultaneously. The event begins in daylight at 18:00 BST (17:00 UT) as Callisto's shadow starts its passage. Ganymede itself appears on disc at this time, but exits from view at 19:19 BST (18:19 UT) under darkening skies. Ganymede's shadow begins its transit at 19:50 BST (18:50 UT) under dark-sky conditions. Callisto's shadow is conveniently positioned on Jupiter's central meridian at this time.

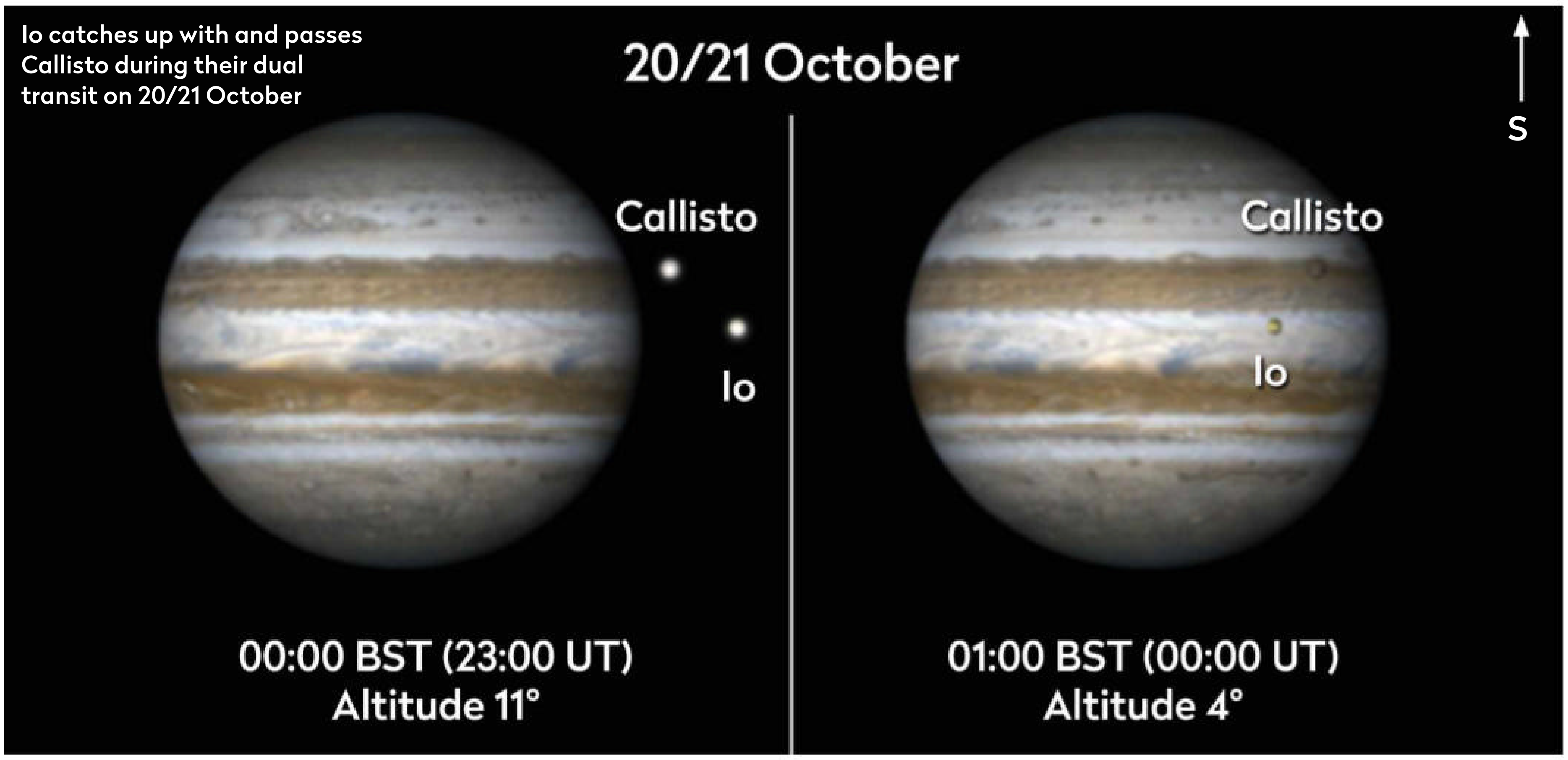
Both shadows pose for an image either side of the central meridian at 20:53 BST (19:53 UT). By the time Callisto's shadow exits the disc at 22:25 BST (21:25 UT), Ganymede's has largely caught up and will leave transit an hour later at 23:25 BST (22:25 UT). The dark nature of both shadows makes this an ideal event to observe through smaller instruments.

Just after midnight BST on 20 October, it's possible to see Io and Callisto in transit at the same time. This event starts at 00:30 BST on 21 October (23:30 UT on 20 October) with both moons lined up as if about to start a race. If it were a race, the clear winner would be Io. Being closer to Jupiter, Io orbits at a much faster pace and, given a flat southwest horizon, it should be possible to see the inner moon striving ahead of the outer moon Callisto. This event occurs near to Jupiter setting and, sadly, concludes with the planet beneath the UK's horizon.

You need a telescope to observe these moon events, but if the sky is clear on the evening of 15 October, there's a meeting between our 77%-lit waxing gibbous Moon and mag. –2.5 Jupiter that should be striking to the naked eye. Both objects will appear at their closest in the early evening as the sky is darkening.

On a plus point, Jupiter is now increasing in altitude as seen from the UK. This year it's in Capricornus and able to reach a height approaching 22° as seen from the centre of the UK. In 2022, that figure increases to around 36°.

Io catches up with and passes Callisto during their dual transit on 20/21 October



ALL PICTURES: PETE LAWRENCE

October meteors

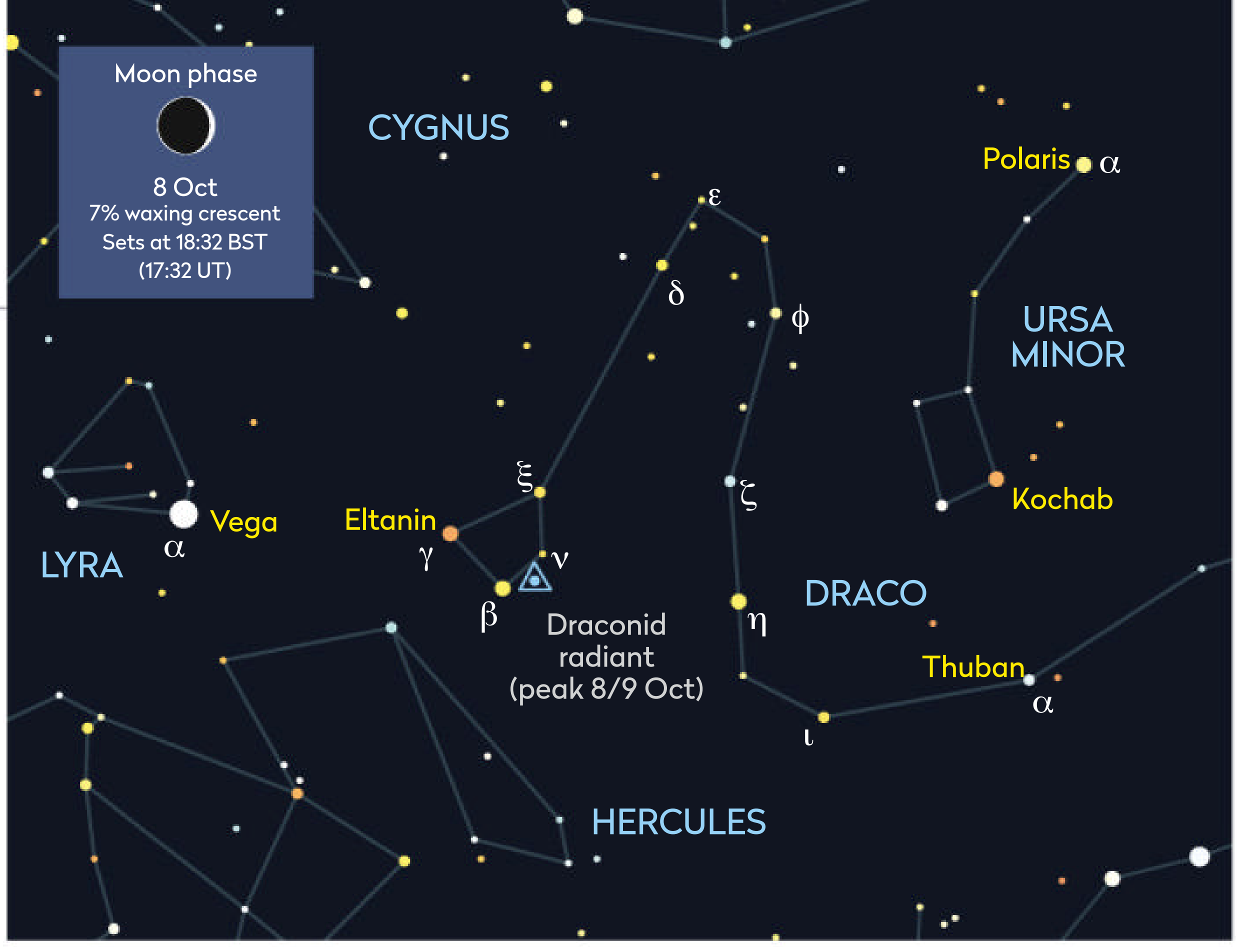
BEST TIME TO SEE: From 20:30 BST (19:30 UT) on 8 October

There's good news and bad news for meteor watching in October. The bad news concerns the annual Orionid shower, which reaches its peak on 21 October. With a peak ZHR of 20 meteors per hour, the Orionids is a popular event to observe. During 2021 however, the peak occurs with a just-past-full Moon in the sky and many of the shower's trails will be lost to its glare.

The good news concerns a lower-rate shower named the Draconids (also known unofficially as the Giacobinids, in reference to the parent comet 21P/Giacobini-Zinner). This shower has a very low ZHR peak value of five meteors per hour, but has shown increased activity over the past few years. The shower put on spectacular displays in 1933 and 1946, with ZHR rates measured at thousands of meteors per hour. Enhanced rates were also seen in 1998, 2005, 2011 and 2012. The 2012 event consisted mostly of very faint trails, which were detected by the Canadian Meteor Orbit Radar facility.

More recently, in 2018 the shower put on an impressive display equating to a ZHR of 150 meteors per hour over a four-hour period. Although there are no predictions for enhanced activity in 2021, the whole point of meteor observing is to record what actually happens regardless of predictions. It's only with recorded data that future predictions can be refined.

Why is this good news? Well, that pesky Moon, which will wipe out a lot of the Orionid shower, is new on Wednesday 6 October and will not interfere with the 2021 Draconids. Draconid meteors are best seen in the evening on 8 October. The shower trails are especially slow, the meteoroids entering Earth's atmosphere at 21km/s – less than one-third the speed of November's Leonid meteorids.



▲ With the Orionids succumbing to a recent full Moon, the Draconids could steal the show

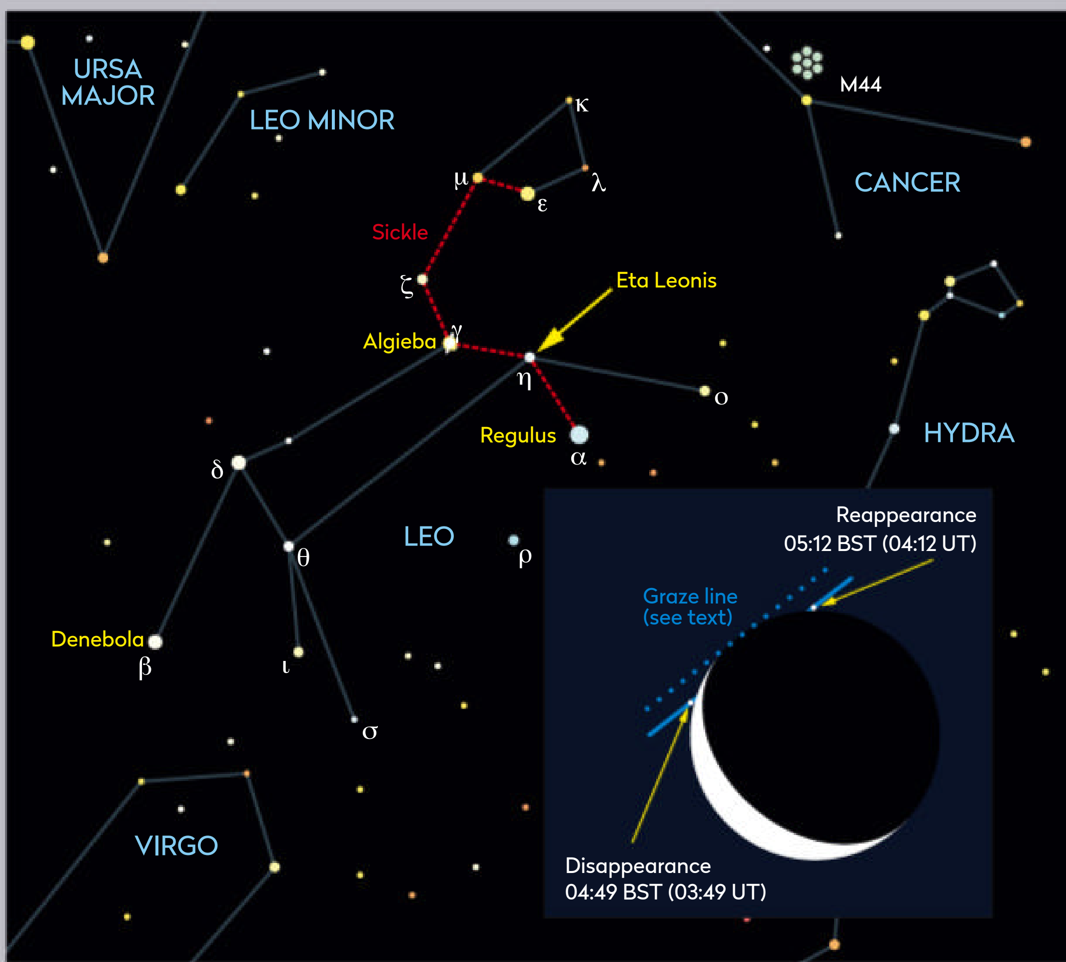
Occultation of Eta Leonis

BEST TIME TO SEE:
3 October from 04:40 BST (03:40 UT) to 05:20 BST (04:20 UT)

Mag. +3.5 Eta (η) Leonis is occulted by a 13%-lit waning crescent Moon on the morning of 3 October, in an event suitable for binoculars or a small telescope. It should also be possible to see Eta Leonis disappear and reappear from behind the Moon's disc with the naked eye.

Eta Leonis is part of the Sickle asterism, which forms the head and foreleg of Leo, the Lion. Regulus (Alpha (α) Leonis) sits at the foot of the Sickle's backwards question mark shape; Eta Leonis immediately north of Regulus.

Eta Leonis disappears behind the Moon's illuminated edge at 04:49 BST (03:49 UT), reappearing from behind the dark limb at 05:12 BST (04:12 UT). The star's line of passage behind the Moon's disc is close to the Moon's northern edge, so there will be a considerable variation in terms of what you will see, depending on your location. North of a line running from Sunderland through St Bees in Cumbria, Ramsey on the Isle of Man, Dundalk in the Republic of Ireland and Lettermore in County Galway, you will see a near miss; south and you'll see it. Along the line described, there's an opportunity to see the star clip the Moon's edge, which is known as a 'grazing lunar occultation'.



▲ Depending on location, you may see the star clip the Moon's edge

THE PLANETS Our celestial neighbourhood in October

PICK OF THE MONTH

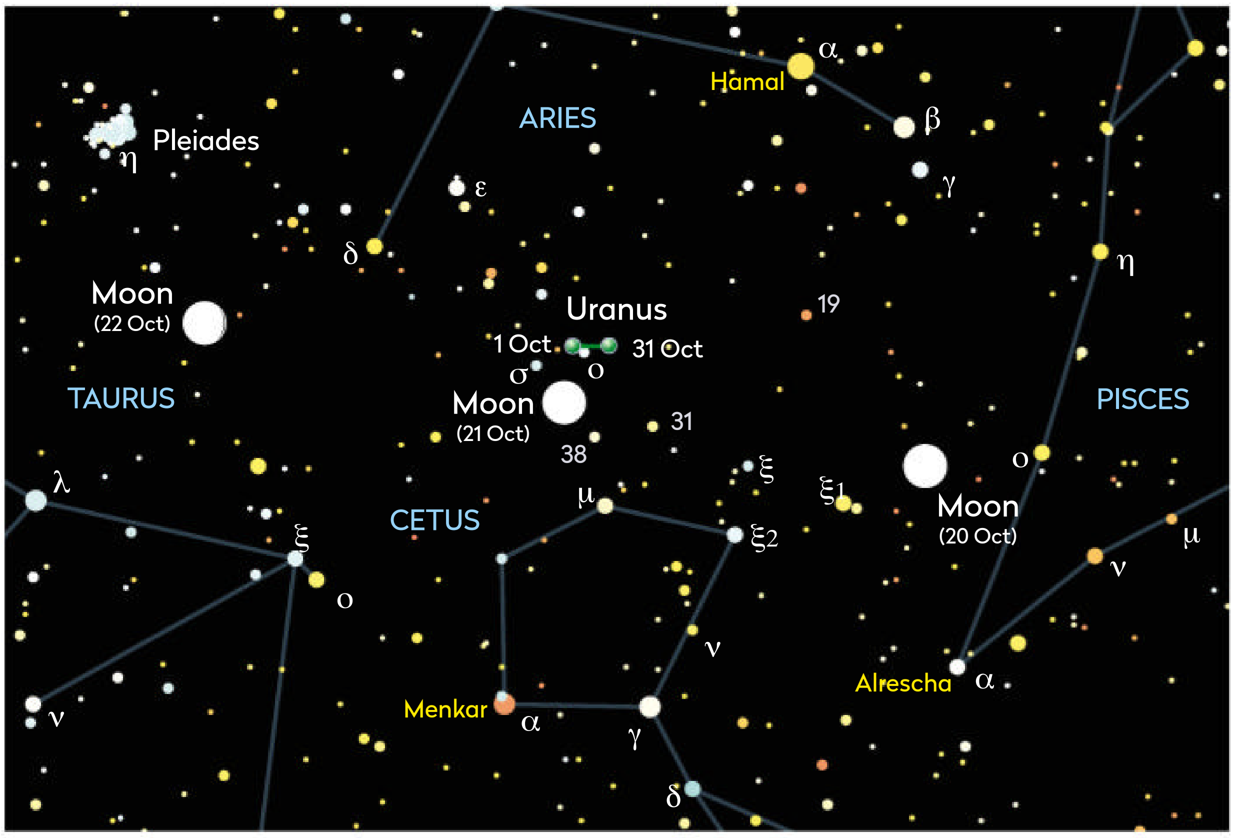
Uranus

Best time to see: 31 October, around midnight UT
Altitude: 52°
Location: Aries
Direction: South
Features: Colour, moons, atmosphere
Recommended equipment: 150mm or larger

Uranus will reach opposition on Thursday 4 November. Around this time the planet appears at its brightest and largest for the year, but its great distance from Earth, means such effects aren't noticeably different to other, non-opposition dates. One benefit of opposition for the outer planets however, is an increased period of observability – they're visible for the entire night.

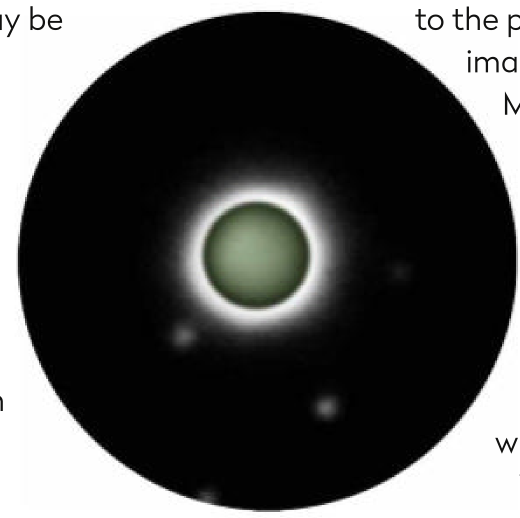
Uranus is currently in Aries, located in the southern part of the constellation, just to the north of the pattern that defines the head of Cetus, the Whale. It shines at mag. +5.7, which means it should be visible to the naked eye from a location with good, dark skies. Through binoculars, Uranus looks exactly like a mag. +5.7 star. A small telescope is required to bring out its distinct greenish hue and reveal its tiny, 3.8 arcsecond disc.

PETE LAWRENCE X 3



▲ October and November sees Uranus at its brightest for the year, between Aries and Cetus

Larger instruments may be able to show banding in the planet's atmosphere as well as some of the brighter moons. Uranus has a current total of 27 officially identified satellites, five of which are big and bright enough to be seen through larger amateur instruments. These moons are Miranda, Ariel, Umbriel, Titania and Oberon. They present a good challenge to see visually and, due to their close proximity to the planet, a challenge to image too. It's easy to lose Miranda in the over-exposed glare of Uranus.

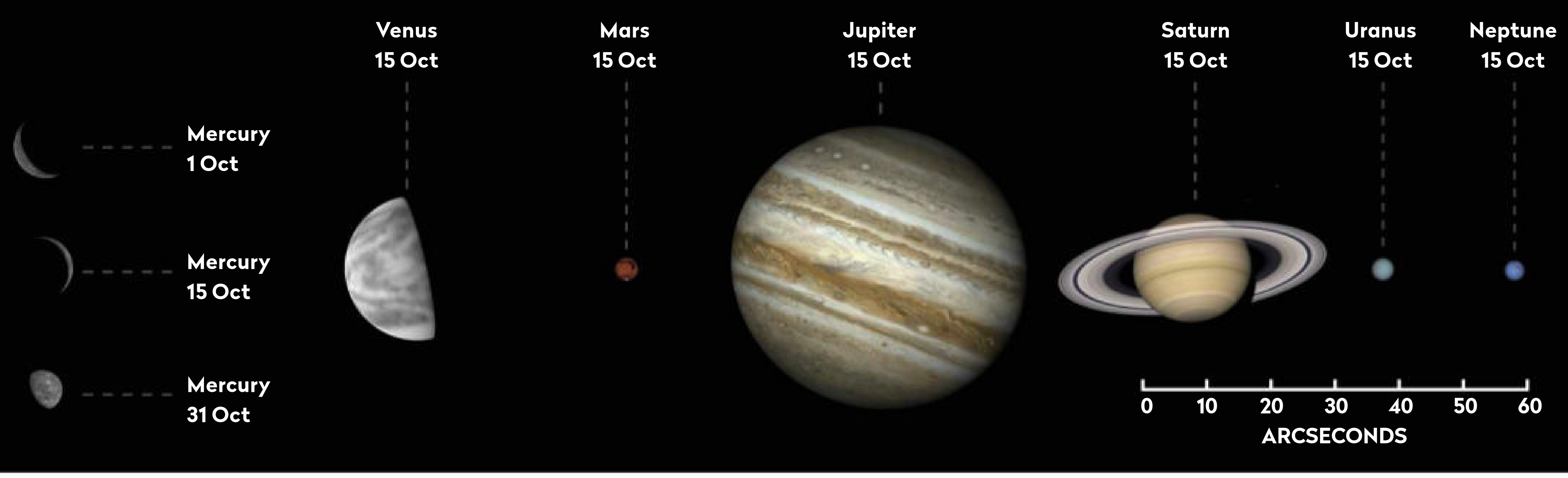


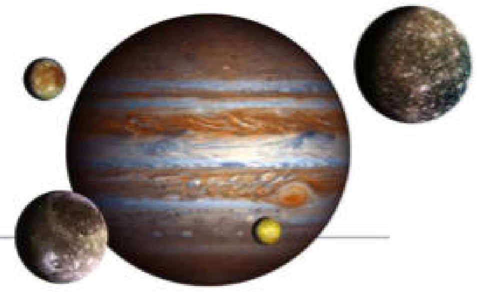
▲ Dim and distant, Uranus may be visible to the naked eye during October

Currently, Uranus is the best-placed planet to observe from the UK, reaching a peak altitude of 52° from the centre of the country, when due south. This lifts it out of the low-altitude atmospheric murk, providing a more stable view. It also increases your chances of spotting its dim dot with your naked eye.

The planets in October

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 25 October, from 1 hour prior to sunrise
Altitude: 7° (low)
Location: Virgo
Direction: East-southeast

Mercury is unlikely to be seen at October's start as it sets at almost the same time as the Sun. Inferior solar conjunction occurs on 9 October. Mercury then rapidly re-emerges into the morning sky, brightening as it does. First sighting is likely on 18 October, when the planet shines at mag. +0.9 and rises 90 minutes before the Sun. When greatest western elongation occurs on the 25th, Mercury will have brightened to mag. –0.5 and have risen around two hours before the Sun. The rest of the month sees Mercury creep back towards the Sun but also grow brighter, reaching mag. –0.8 on 31 October.

Venus

Best time to see: 29 October, 20 minutes after sunset
Altitude: 6.5° (low)
Location: Ophiuchus
Direction: South-southwest

Venus reaches its greatest eastern elongation on 29 October, 47° from the Sun. But the planet's relative position is poor and it remains low after sunset all month. On 1 October Venus sets one hour after the Sun. By the end of the month, that delay will have increased to 100 minutes. In theory Venus reaches a 50%-illuminated phase on 28 October, but a phase anomaly effect should mean it appears half-lit a few days earlier.

A 14%-lit waxing crescent Moon sits 2.2° from Venus on the evening of 9 October.

Mars

Mars is in conjunction with the Sun on 8 October and not visible this month.

Jupiter

Best time to see: 1 October, 22:10 BST (21:10 UT)
Altitude: 22°
Location: Capricornus
Direction: South

Jupiter is high in the early evening sky during October so ideal for observing. On 1 October from the centre of the UK it appears 22° up when due south at 22:10 BST (21:10 UT). By the end of the month it reaches this position at 19:12 UT. A waxing gibbous Moon sits near the planet on the evenings of 14 and 15 October.

Saturn

Best time to see: 1 October, 21:00 BST (20:00 UT)
Altitude: 18°
Location: Capricornus
Direction: South

Shining at mag. +0.5 on 1 October, Saturn reaches an altitude of 18°, its highest point, due south around 21:00 BST (20:00 UT). While still low, this is an improvement over recent years. A waxing gibbous Moon passes south of Saturn on 13 and 14 October. By the end of the month, Saturn will still reach its highest point in relative darkness, but there'll be a residual of the evening twilight behind the planet.

Neptune

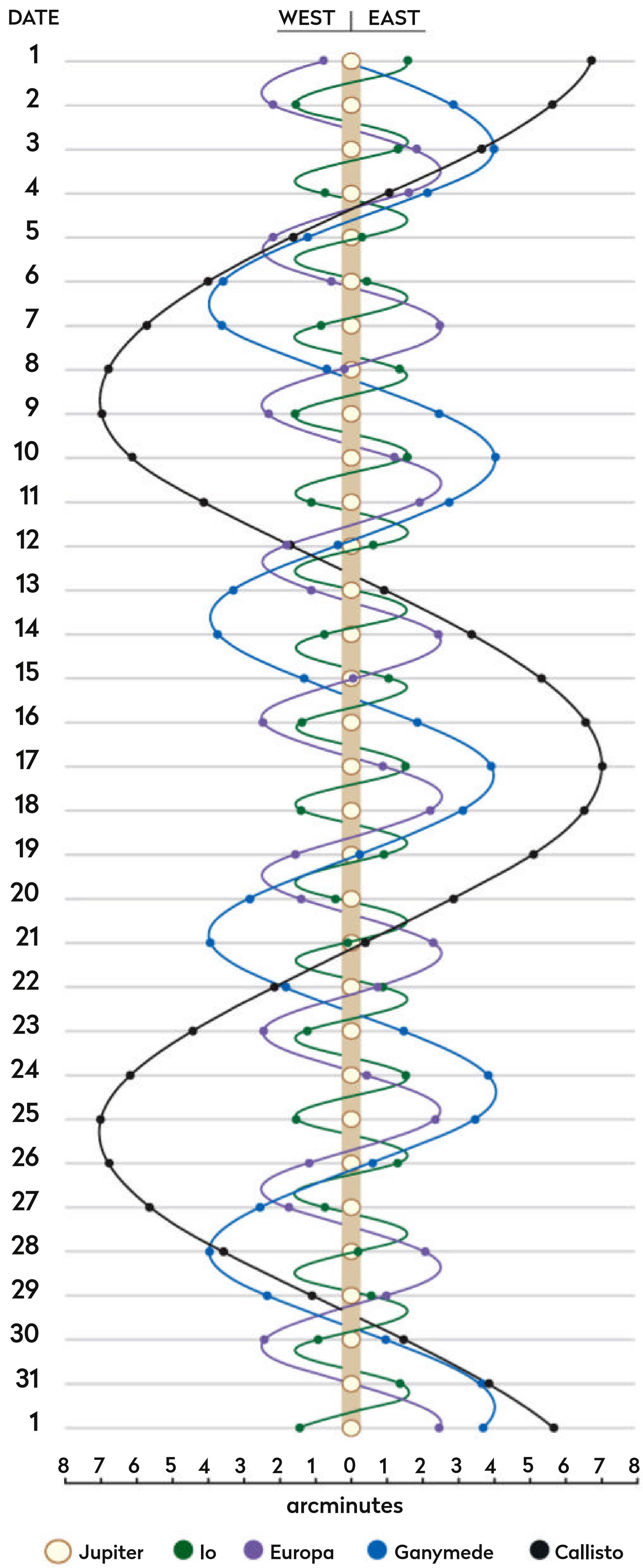
Best time to see: 1 October, 00:00 BST (23:00 UT)
Altitude: 32°
Location: Aquarius
Direction: South

Neptune is well positioned in October. Currently located in eastern Aquarius near to mag. +4.2 Phi (ϕ) Aquarii, Neptune shines at mag. +7.8 and is, theoretically, the only main planet that requires optical assistance to see.

More ONLINE
Print out observing forms for recording planetary events

JUPITER'S MOONS: OCTOBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – OCTOBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- N E S W 5° — COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

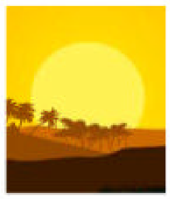
1 October at 01:00 BST
15 October at 00:00 BST
31 October at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in October*



Date	Sunrise	Sunset
1 Oct 2021	07:12 BST	18:46 BST
11 Oct 2021	07:30 BST	18:23 BST
21 Oct 2021	07:48 BST	18:00 BST
31 Oct 2021	07:07 UT	16:39 UT

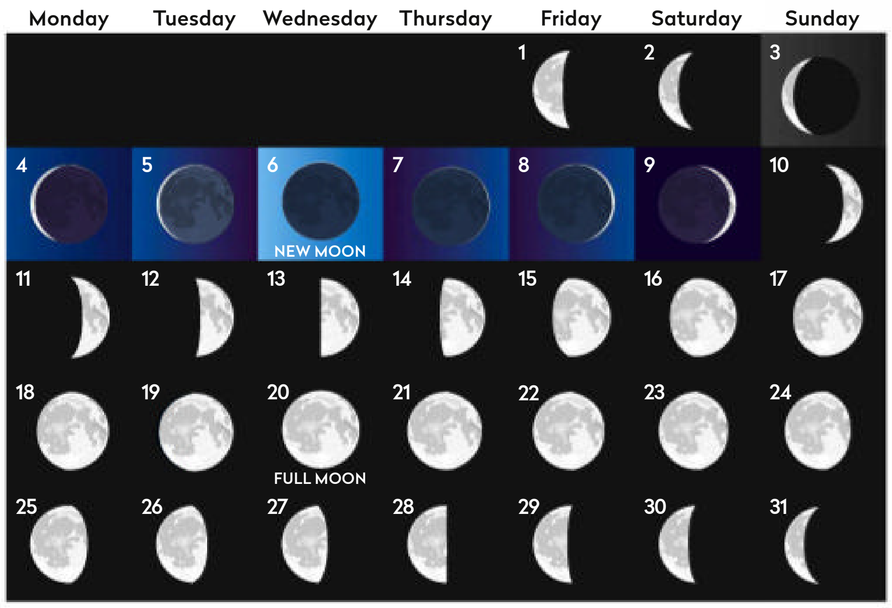
Moonrise in October*

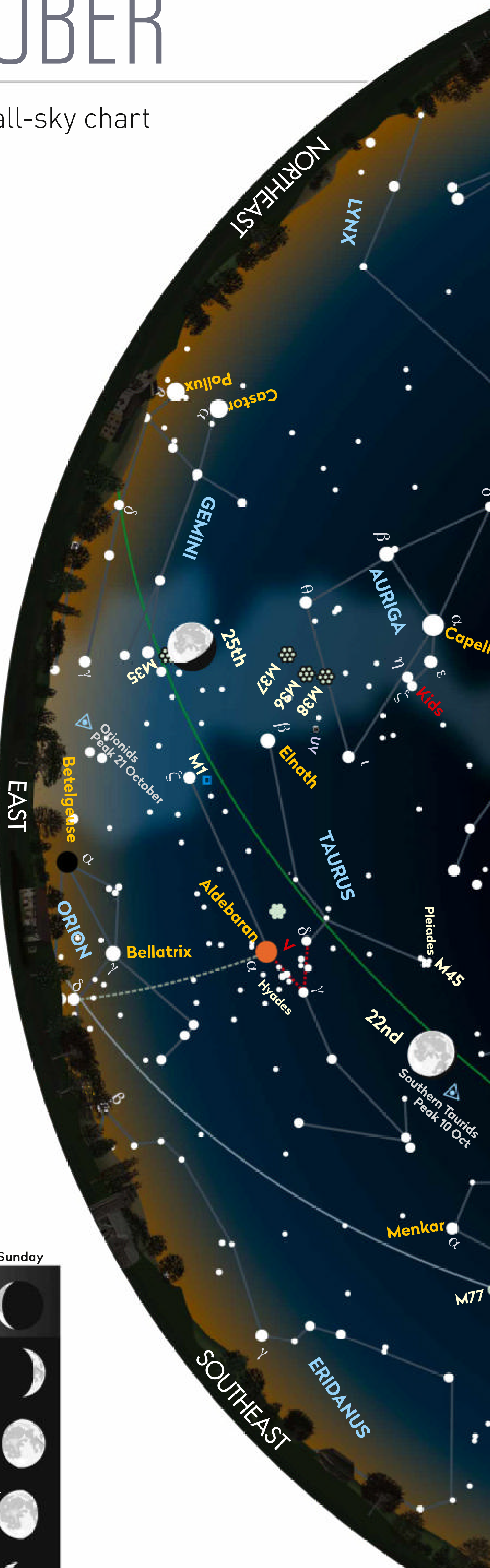
Moonrise times

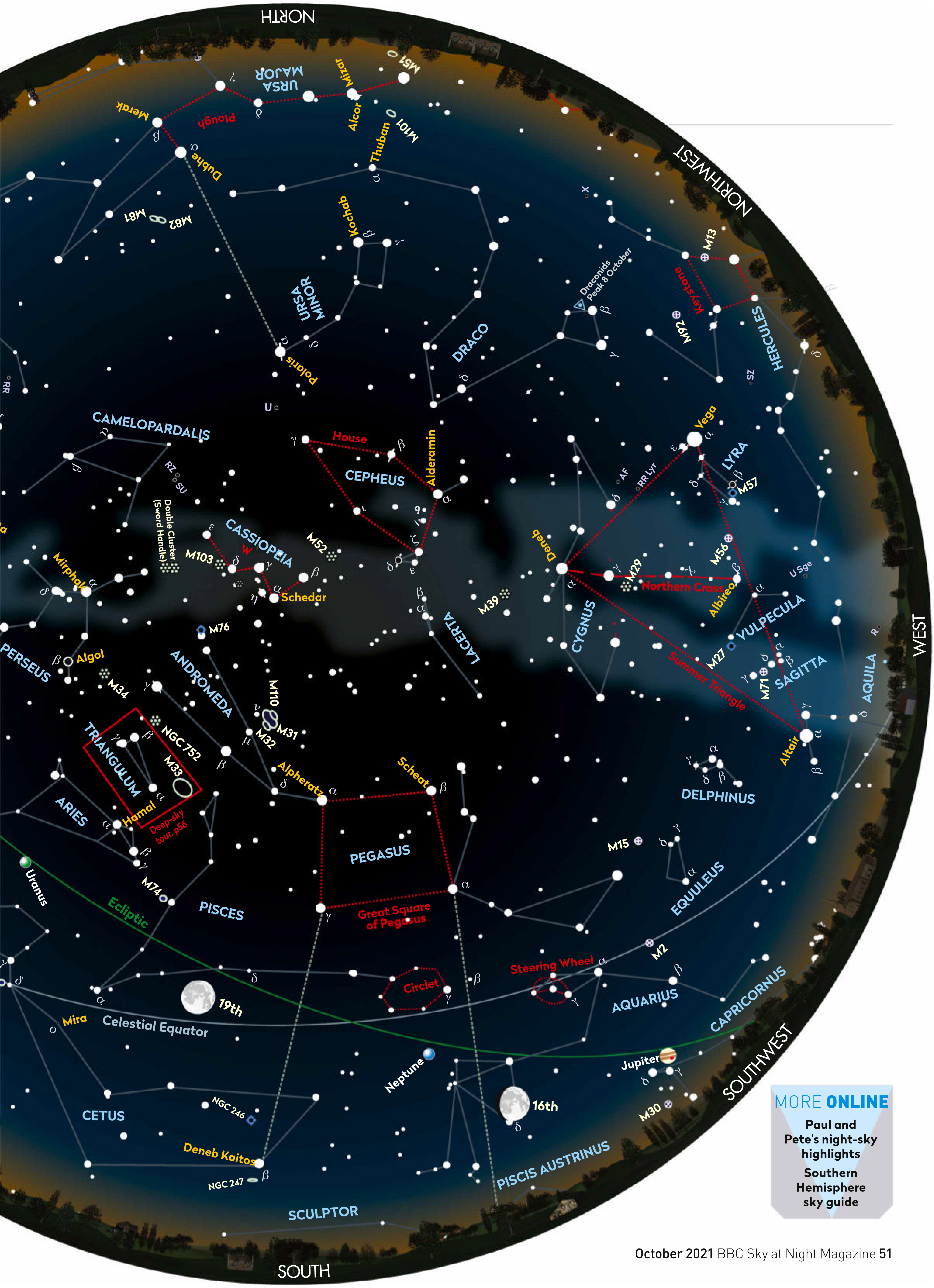
1 Oct 2021, 00:09 BST	17 Oct 2021, 17:44 BST
5 Oct 2021, 05:31 BST	21 Oct 2021, 18:31 BST
9 Oct 2021, 11:28 BST	25 Oct 2021, 20:06 BST
13 Oct 2021, 16:16 BST	29 Oct 2021, --:-- BST

*Times correct for the centre of the UK

Lunar phases in October







MORE ONLINE

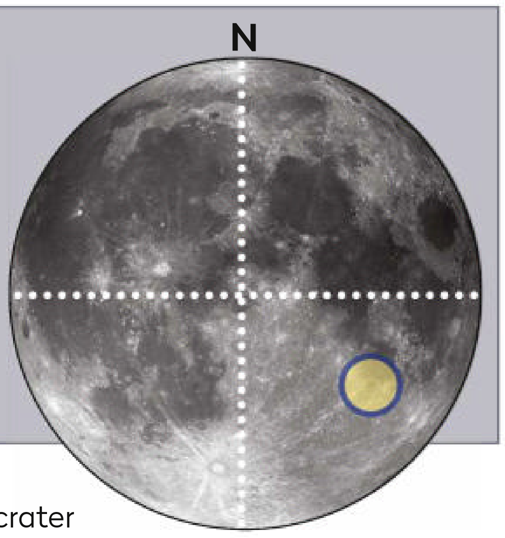
Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH October's top lunar feature to observe

Fracastorius

Type: Crater
Size: 124km
Longitude/Latitude: 33.1° E, 21.4° S
Age: Older than 3.9 billion years
Best time to see: Five days after new Moon (10 & 11 October) or four days after full Moon (24 & 25 October)
Minimum equipment: 10x binoculars



Fracastorius is a beautiful lava-flooded crater on the southern edge of 350km **Mare Nectaris**. Appearing ancient and battered, it manages to maintain a resplendent dignity in much of its outline, with all but the northern section still clearly visible. The northern section could be described as 'almost there', hinted at by roughness in the area together with lighter surface markings.

The eastern rim rises to a height around 1.8km. It is narrowest to the north, with a curious unnamed feature near where it loses altitude towards the surface of Mare Nectaris. The unnamed feature is 11km across and looks like three co-joined and flooded craters. The craters appear at 120° intervals around their common overlap point, the whole structure showing good three-way symmetry.

Fracastorius's eastern rim arc supports a well-aimed 3.5km craterlet. As you head south from this craterlet, the rim curves to the west, widening as it goes, until it reaches an average width of around 17km. At its southernmost point, the rim appears to widen and spill further to the south. A depression sits immediately west of this extension, formed in part from the 12km crater **Fracastorius Y**.

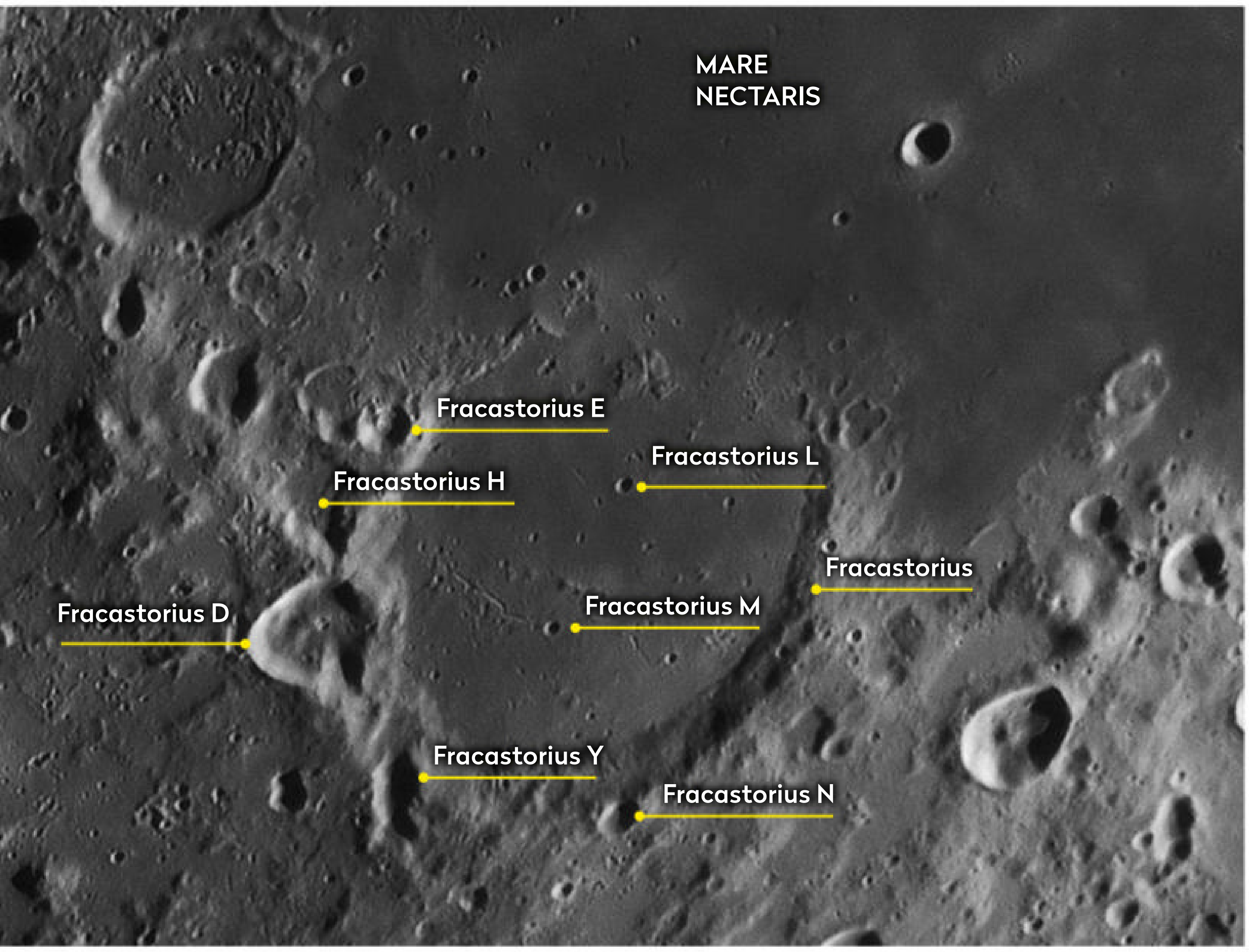
A small crater valley chain extends north-northwest from Y, the depressions obliterating the outer part of Fracastorius's southwest rim. The short chain ends at the north with a crater which used to be known as Romana but is now officially recognised as **Fracastorius D**. At 28km, D is easy to spot and is interesting in that its overall shape is more triangular than round. The rim of Fracastorius continues from the northern point of D's outer edge, passing poorly defined 21km **Fracastorius H** before encountering 13km **Fracastorius E**. The rim elevation drops sharply after E, narrowing to a point along the north-northwest boundary.

There are craterlets within Fracastorius that can be seen with smaller instruments

The missing northern rim is, as mentioned earlier, hinted at by a mish-mash of features. Most obvious is a 9.3km x 12km bifurcated rectangular massif, presumably part of the original rim, high enough to withstand the incoming lava flow.

Internally, Fracastorius is almost smooth. There are a number of craterlets which can be seen with smaller instruments, most notably 5km **Fracastorius L** in the northern half of the crater, and 4km **Fracastorius M** in the southern half. The southern half of the main floor appears rougher, covered in a number of low-level hills. There is a hint of elevation in the centre, the remains of the original central mountain complex perhaps. However, this isn't very dramatic, more a series of east-west orientated bumps rising to a peak height of around 600m.

A fine rille (narrow channel) winds its way across the crater's floor. Orientated east-west, the rille passes south of the central 'mountain' complex, appearing to clip the northern edge of Fracastorius M. In high resolution images the rille appears to split as it heads east of centre but this is misleading; the main part of the rille continues as expected, eventually arcing north to run along the inside of the eastern rim. The southern 'split' section can be seen in high-resolution satellite images to be comprised of numerous tiny craterlets.



▼ The crater's name, Fracastorius, commemorates the Italian scholar, astronomer and poet Girolamo Fracastoro

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

View Comet 4P/Faye as it passes slightly to the east of Betelgeuse

Comet 4P/Faye puts on a faint but steady performance this month, passing through a region of sky across Orion's Club and through to the southwest corner of Gemini. 4P/Faye's magnitude holds steady at +11.5 all month. Starting its path 9˚ north and slightly east of Betelgeuse (Alpha (α) Orionis), the comet tracks east in October, gaining a more southeast trajectory at the month's end to position it a little over a degree south of mag. +3.3 Xi (ξ) Geminorum. As a handy guide to sky distance, the apparent separation of Rigel (Beta (β) Orionis) and Mintaka (Delta (δ) Orionis) is 9˚, while the gap between Xi and 30 Geminorum – the mag. +4.5 star slightly northwest of Xi – is half a degree.

4P/Faye is a periodic comet with an orbital period of 7.55 years. It's a Jupiter-family comet, a class which describes comets with a period of less than 20 years and orbital inclinations less than 30˚. Faye's orbit takes it in as close as 1.666 AU from the Sun at perihelion and out as far as 6.026 AU at aphelion. The last perihelion occurred on 8 September of this year.

4P/Faye is named after Hervé Faye, a French astronomer who first observed the comet on 23 November 1843, with confirmation coming on the 25th. The discovery was made possible because the comet was passing close to Earth at the time, making it appear bright.

This month, 4P/Faye is best seen with medium to large telescopes. Smaller instruments should be able to pick it up in a dark sky. Its position north of Orion is favourable, this area of sky reaching greatest altitude in the early hours of the morning.

▲ **Look for Comet 4P/Faye in the early hours of the morning**

STAR OF THE MONTH

Sadalmelik, a bright gem of Aquarius

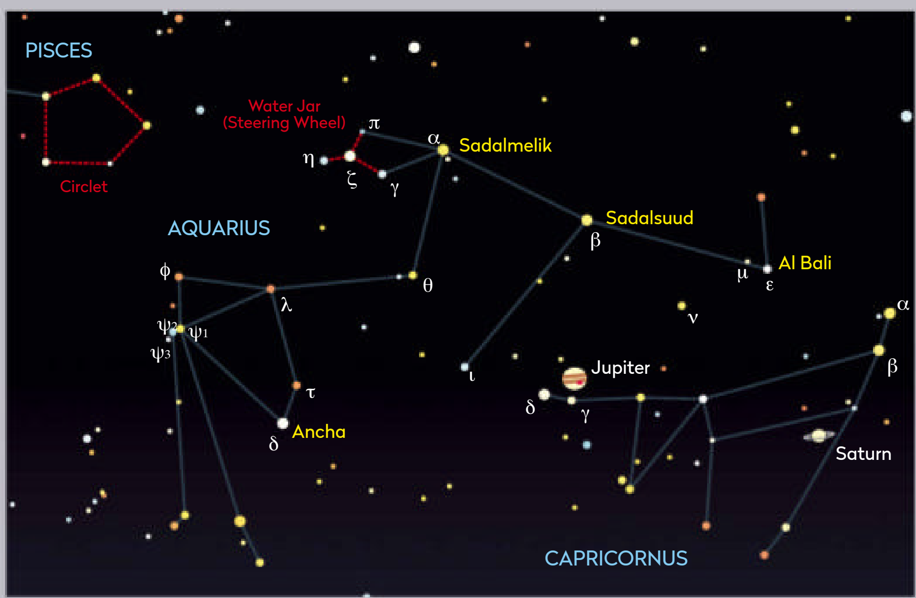
It's fair to say that the constellation of Aquarius, the Water-Bearer, is ill-defined. Apart from a small pattern of four stars arranged as a triangle with one in the centre, known as the Water Jar asterism, the rest is sprawling and not the easiest to pick out. The two brightest stars are Sadalmelik (Alpha (α) Aquarii) and Sadalsuud (Beta (β) Aquarii). Sadalmelik sits west of the Water Jar.

Shining at mag. +2.93, Sadalmelik is the second brightest star in Aquarius after mag. +2.87 Sadalsuud. It's a distant star, 520 lightyears from the Sun, closer than Sadalsuud's 540 lightyears. Their meanings are similar. Sadalmelik is derived from the Arabic meaning "luck of the king" while Sadalsuud means "luck of lucks". As an aside, Sadalmelik is one of only a handful of stars with proper names which are located within a degree of the celestial equator. The others are Mintaka (Delta (δ) Orionis), Zaniah (Eta (ε) Virginis) and Heze (Zeta (ζ) Virginis).

Estimated to be 53 million years old, Sadalmelik is a supergiant star of spectral classification G2 Ib. G2 is the same spectral type as our Sun, and the star's temperature is close to our Sun's 5,505˚C at 5,110˚C. Sadalmelik has 5.1 times the mass, is 53 times larger and has a luminosity 2,120 times greater than the Sun. Its supergiant status indicates it is a highly evolved object that is now dying.

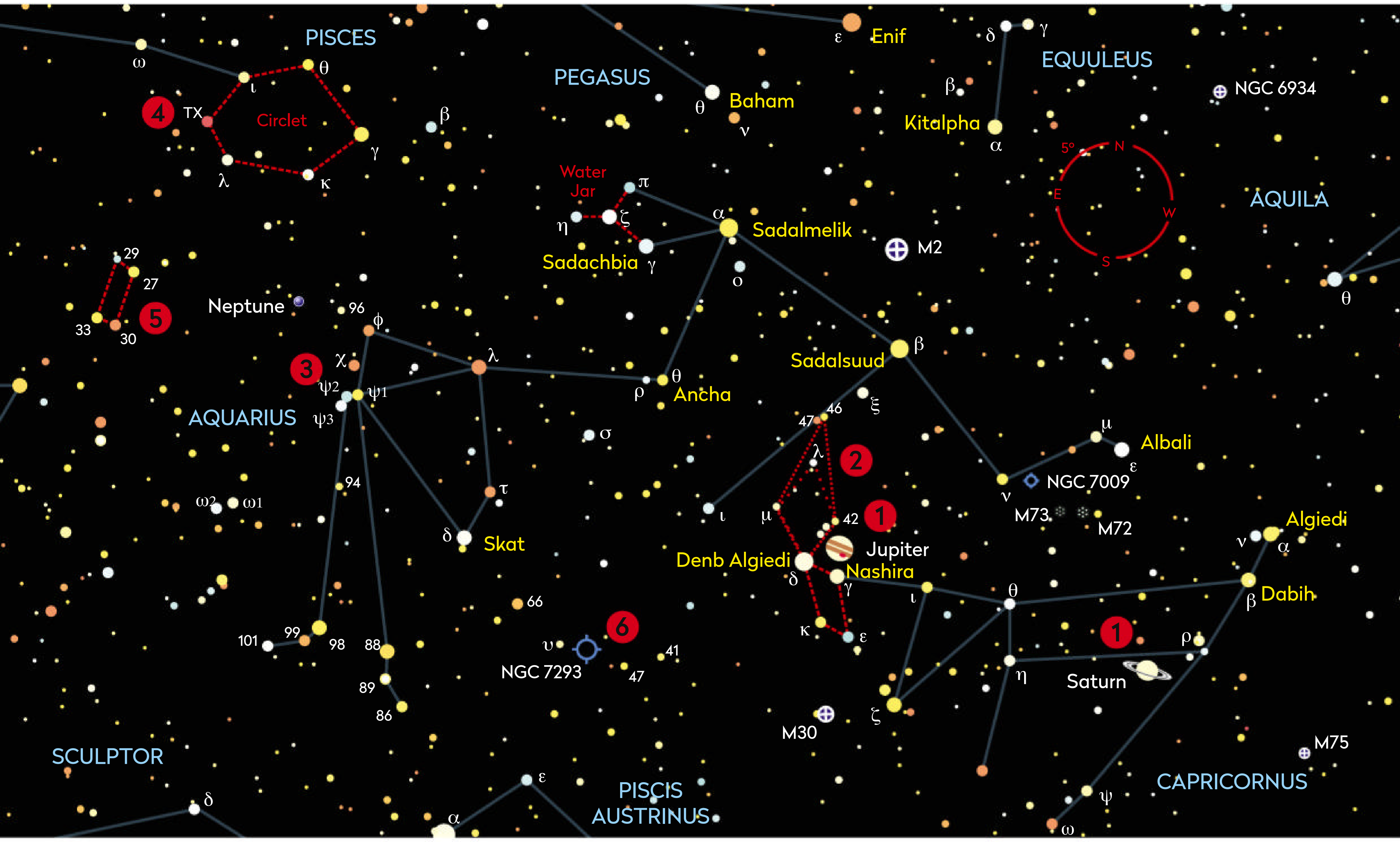
Despite appearing 10˚ apart both stars share similarities; they are close in brightness and are placed at a similar distance from Earth. Sadalsuud is also a supergiant with a spectral type of G0 Ib. It has a similar mass, radius and luminosity to Sadalmelik; compared to the Sun the values being 5.0, 48 and 2,046 times respectively. The major difference is age; Sadalsuud is twice as old as Sadalmelik.

▼ **Sadalmelik and Sadalsuud appear separated by 10˚ in Aquarius**



BINOCULAR TOUR With Steve Tonkin

Locate wide-field wonders, including two parallelograms in Pisces and Capricornus



1. Jupiter's and Saturn's moons

10x50 Start by finding the 'sweet spot' in your field of view where the binoculars' chromatic aberration partly counteracts atmospheric dispersion and Jupiter's colour-fringing is minimal. Don't expect to see planetary detail with 10x50 binoculars, but you can plot the night-to-night dances of the gas giants' moons. Jupiter's Galilean moons and Saturn's brightest moon, Titan, are easy to spot when they are separated from the planet by more than an arcminute. ☐ **SEEN IT**

2. Capricorn's rhombus, kite and parallelogram

10x50 One way of remembering star patterns in different regions of the sky is to use familiar shapes as aide-mémoires. Delta (δ) Capricorni is common to three quadrilateral asterisms. It makes a rhombus with Mu (μ), Lambda (λ) and 42 Capricorni; a kite if we include 46 Capricorni instead of λ; and a parallelogram with Nashira (Gamma (γ)), Epsilon (ε) and Kappa (κ) Capricorni. What other shapes can you find in this region of sky? ☐ **SEEN IT**

3. Psi Aquarii star field

10x50 This star field contains stars of the main spectral classes except O, so you can use it to get a sense for the colours of each. Psi² (ψ²) Aquarii is B, Psi³ (ψ³) Aquarii is A, 96 Aquarii is F, 94 Aquarii is G, Psi¹ (ψ¹) Aquarii is K, and Chi (χ) Aquarii and Phi (φ) Aquarii are both M. Also seek Neptune, which is 2° east of 96 Aquarii and is easy to view in binoculars, if you know where to look. ☐ **SEEN IT**

4. TX Piscium

10x50 The easternmost star in the southern circlet of Pisces is one of the reddest in the sky, the variable (mag. +4.8 to +5.2) TX Piscium. This ruby droplet is a carbon star: it pulsates in size, brightening as it expands, then throws off layers of soot as it contracts, making it dim. ☐ **SEEN IT**

5. The Pisces parallelogram

10x50 7.5° southeast of TX Pisces we find another quadrilateral asterism. This 3° x 1° parallelogram has 27, 29, 30 and 33 Piscium at its corners. The northeast corner is blue-white 29 Piscium, and diagonally opposite is orange 30 Piscium. The other two corners appear yellowish. At first glance, the parallelogram seems to be empty: it contains only one star brighter than 8th magnitude. ☐ **SEEN IT**

6. The Helix Nebula, NGC 7293

15x70 You'll need a good southern horizon, along with a transparent sky and full dark-adaptation, if you want to observe this planetary nebula. Use the chart to identify Upsilon (υ) Aquarii and 47 Aquarii. About a third of the way from Upsilon Aquarii to 47 Aquarii you'll find a faint circular patch about 10 arcminutes in diameter. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

This month, see if you can locate the presence of a black hole at Cygnus X-1

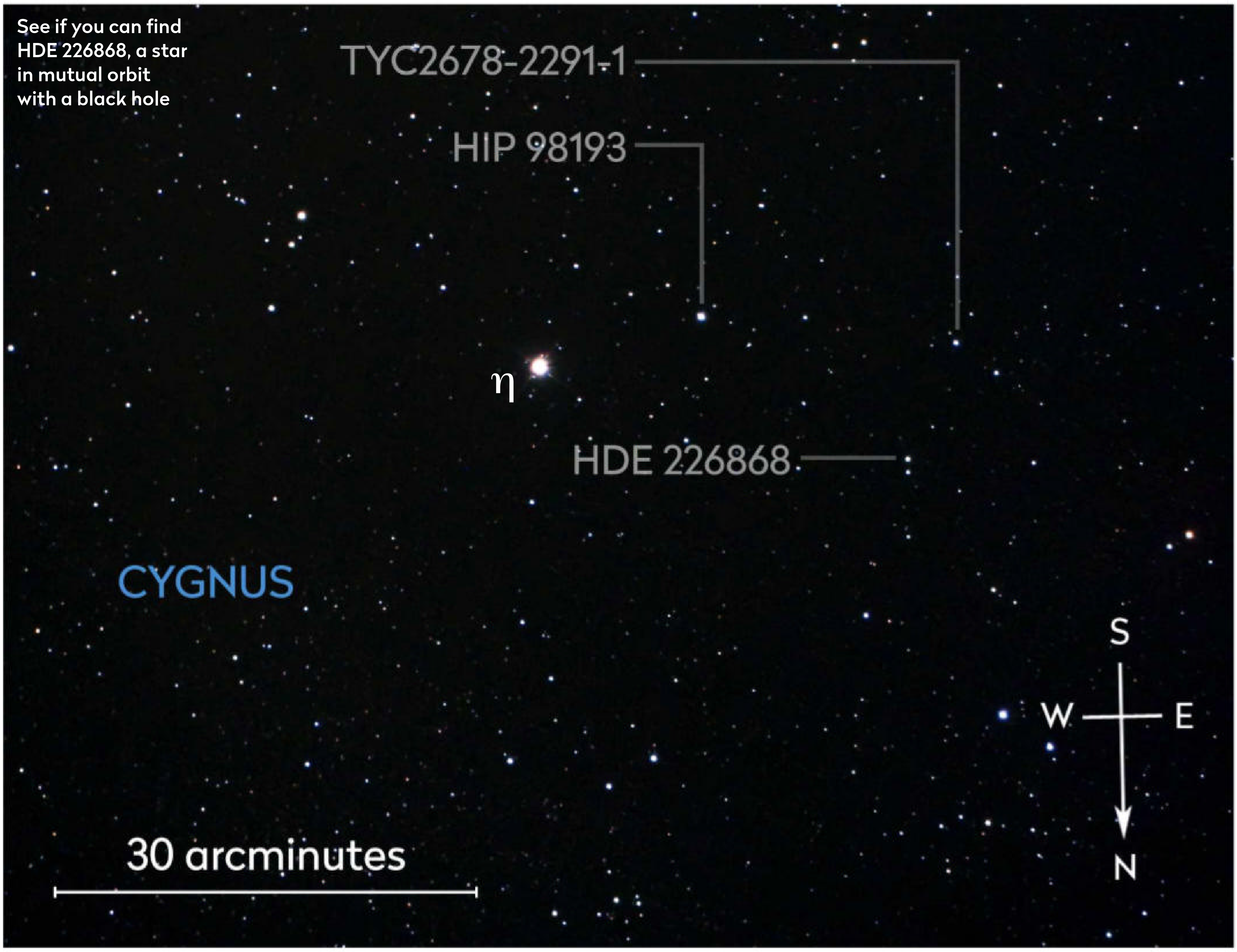
This month's challenge is unusual in that the object you're trying to find can't be seen. Cygnus X-1 is a source of X-rays in our Galaxy and the first such source to be attributed to the presence of a black hole. A black hole is basically an object so massive that its escape velocity has exceeded the speed of light. As a consequence, no light can escape the object, leading to many strange space and time related phenomena. From an observational standpoint, Cygnus X-1 is essentially invisible to the naked eye.

This isn't the end of the challenge though, for Cygnus X-1 is one component in a high mass X-ray binary system. The other component is a supergiant variable star HDE 226868 (HIP 98298), which shines at mag. +9.0 and can be seen through a small scope. The objects orbit around one another, separated by just 0.2 AU. HDE 226868's stellar wind removes material from the star, which ends up spiralling around the black hole. The resulting accretion disc around the black hole is energetic and hot. This is the source of X-rays that gave away the existence of the HDE 226868's companion black hole.

The challenge is to locate HDE 226868. The black hole can't be seen and this object's existence and nature will need to be provided by your imagination. The black hole is believed to have a mass equivalent to 21.2 solar masses contained within an effective radius of 44km.

Locating a ninth magnitude star isn't in itself a complex task. However, it's located in Cygnus, against the background of the Milky Way and this will make it trickier. The key is to locate the mag. +3.9, naked-eye star Eta (η) Cygni, which is located in the neck of the Swan between Sadr (Gamma (γ) Cygni) and Albireo (Beta (β) Cygni). Look at the mid-point between these two easy naked-eye stars and offset slightly towards Sadr to identify Eta.

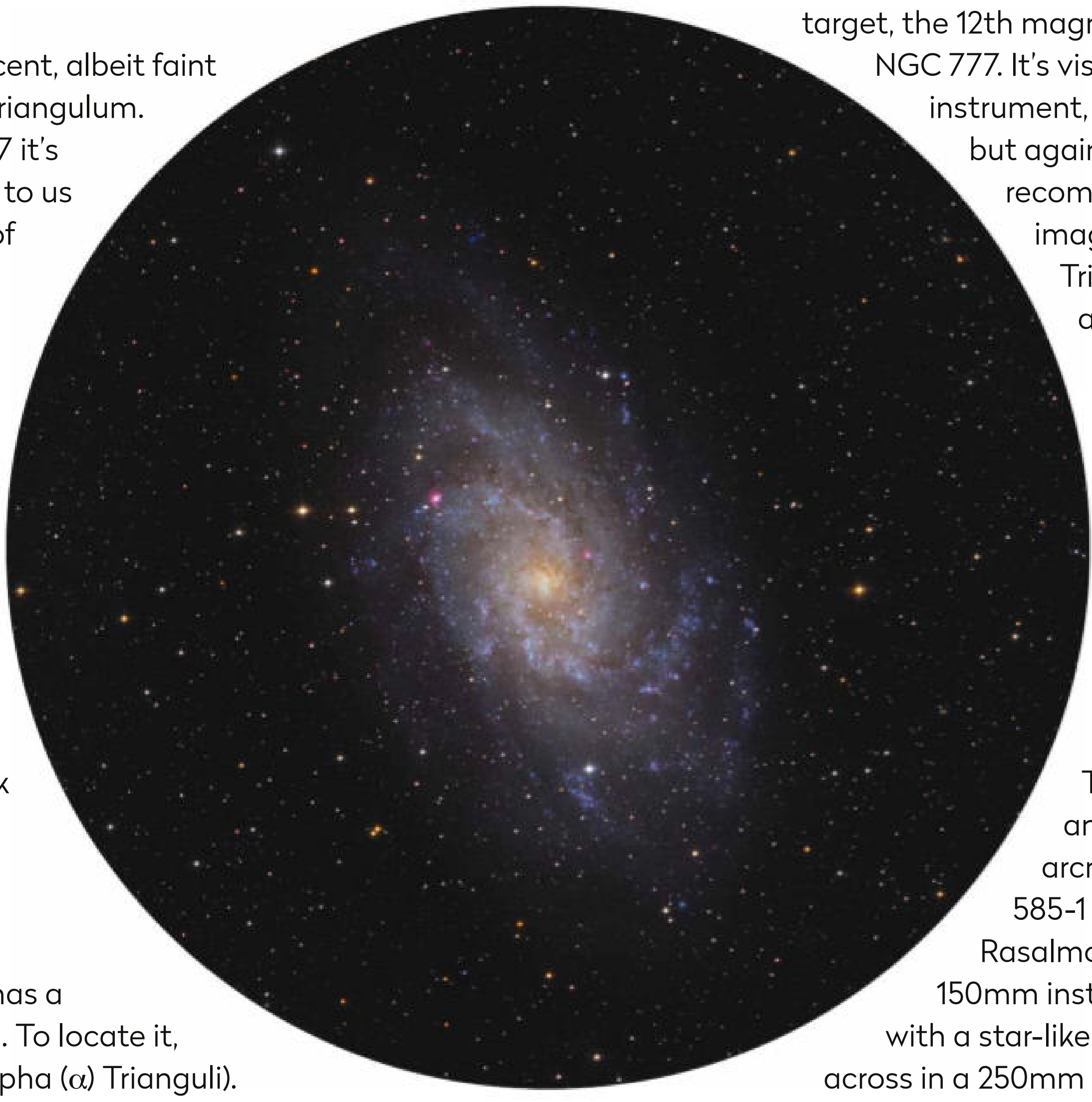
HDE 226868 is located 25 arcminutes east and 6 arcminutes north of Eta Cygni. To star hop to the target, centre up on Eta Cygni. Look 11 arcminutes to the east to find mag. +7.3 HIP 98193. Now head 18 arcminutes east of HIP 98193 to get to mag. +8.9 TYC2678-2291-1, a star of similar brightness to HDE 226868. Drift 8 arcminutes to the north of TYC2678-2291-1 and a fraction west to locate HDE 226868 with a mag. +10 star an arcminute to its north. It may not look that special, but by observing HDE 226858 you're also looking at a black hole!



See if you can find HDE 226868, a star in mutual orbit with a black hole

DEEP-SKY TOUR

Take in magnificent galaxies in the vicinity of Triangulum, the Triangle



▲ View the Triangulum Galaxy, M33, through a 250mm telescope to reveal the mottled patchwork of the spiral galaxy

CHRISTOPH KALTSEIS/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 M33

M33 is a magnificent, albeit faint spiral galaxy in Triangulum. Although listed at mag. +5.7 it's hard to see. M33 is face-on to us and with an apparent size of 62 x 39 arcminutes, its surface brightness is low. Locate it by extending the line from M31, the Andromeda Galaxy, through Mirach (Beta (β) Andromedae) for the same distance again. A small scope under dark skies will show the central core as a misty fuzzball. A 250mm scope shows a mottled patchwork of dim light surrounding the core. ☐ **SEEN IT**

2 Collinder 21

Our next target has a charm all its own. To locate it, start at Rasalmothallah (Alpha (α) Trianguli). Head 2.4° south and 0.7° west, where you'll find a mag. +8.1 star with a curve of 10th magnitude stars to its north. This is the cluster Collinder 21. The semi-circle has a diameter of 6 arcminutes. A small scope reveals six stars here, a 250mm instrument increasing the count to 14. ☐ **SEEN IT**

3 NGC 672 (and IC 1727)

Heading 0.6° northwest from the brightest star in Collinder 21 brings you to NGC 672, a spiral galaxy located 23.4 million lightyears away. A 150mm scope reveals the object to be elongated, with a hint of brightness at its centre. With a visual magnitude of +10.8 and a size 6.6 x 2.7 arcminutes, like M33, NGC 672 suffers from low surface brightness. This is an interacting galaxy, deformed by gravitational forces inflicted by IC 1727, a mag. +12.1 irregular galaxy located 6 arcminutes to the west. A 250mm instrument reveals NGC 672 to be 4 arcminutes long and 1.5 arcminutes wide. ☐ **SEEN IT**

4 NGC 777

We head inside the pointed isosceles triangle that is Triangulum for our next target, the 12th magnitude elliptical galaxy NGC 777. It's visible in a 150mm instrument, despite its dim magnitude, but again dark skies are recommended. To locate it, imagine the middle line of the Triangulum triangle starting at Rasalmothallah. Head 2.4° along this line from Rasalmothallah where you'll find a mag. +8.7 star with a mag. +9.3 star 6.5 arcminutes to the west: TYC2308-878-1 and TYC2308-585-1 respectively. NGC 777 forms a right-angled triangle with these stars, TYC2308-585-1 at the right angle. The galaxy lies 4.7 arcminutes from TYC2308-585-1 in a direction away from Rasalmothallah. It's dim in a 150mm instrument, a misty patch with a star-like nucleus; and is 1 arcminute across in a 250mm scope. ☐ **SEEN IT**

5 NGC 784

For our penultimate target, the virtually edge-on barred spiral galaxy NGC 784, head 2.3° southeast of Rasalmothallah to locate mag. +6.6 HIP 9493. You'll find NGC 784 28 arcminutes to the north of this star. Again, this galaxy is listed at a reasonably bright mag. +11.8 but suffers from low surface brightness. A 150mm scope will show it as a faint scratch of light orientated north-south. A large scope is necessary to do it justice, the galaxy appearing 6 arcminutes long and nearly an arcminute wide through a 300mm instrument. The mistiness of the galaxy's elongated halo surrounds a brighter inner region roughly 1.5 arcminutes in length. Through larger instruments, there's a definite mottled texture across the galaxy's length. ☐ **SEEN IT**

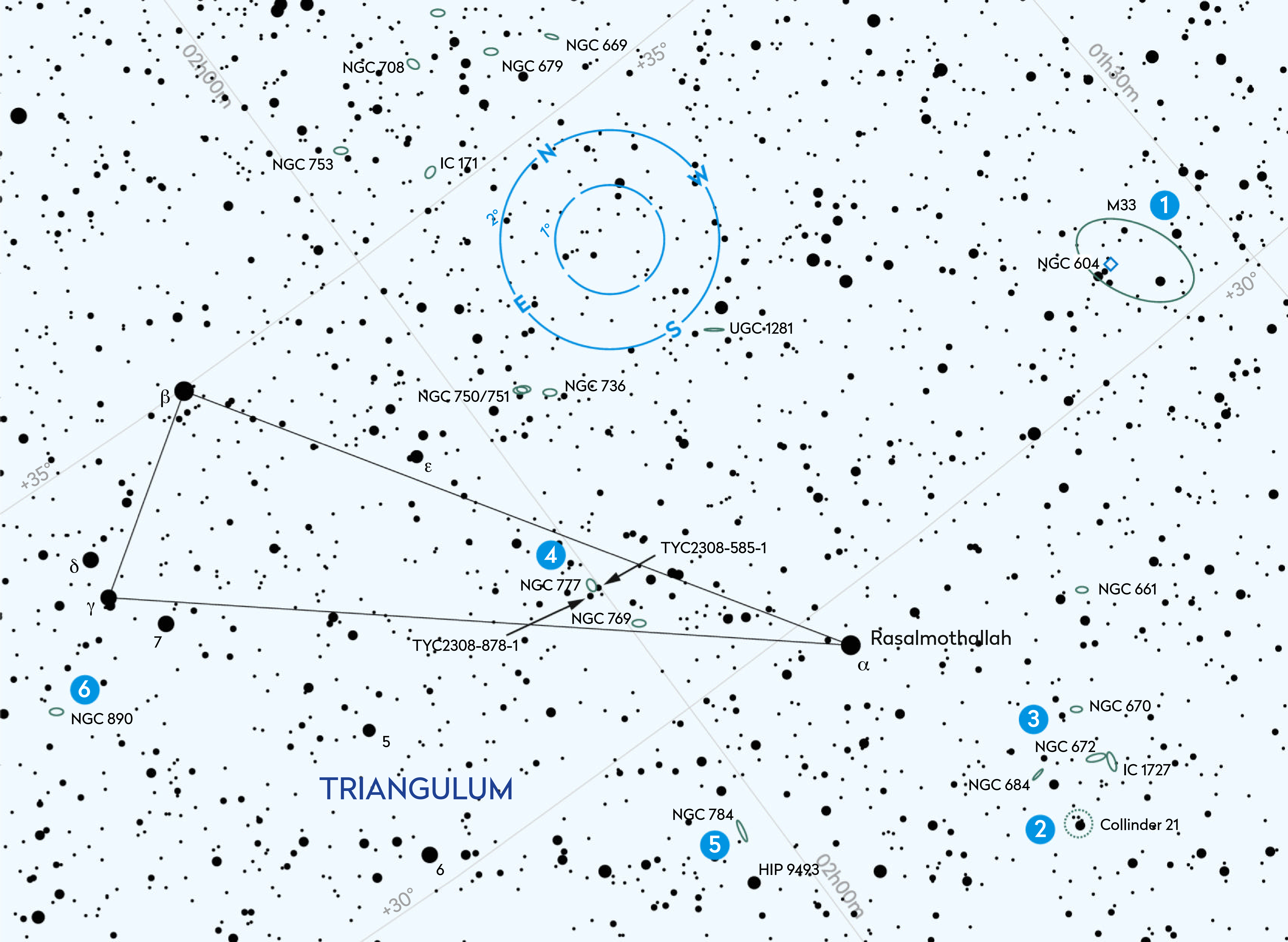
6 NGC 890

Our final target is NGC 890, an 11th magnitude lenticular galaxy sitting 1.1° east-southeast of Gamma (γ) Trianguli in a barren area of sky. The best strategy to locate it is to use the short edge of Triangulum formed by drawing a line from Beta (β) through Gamma Trianguli. Keep this line going for about half the distance again and you'll be in the right area. Listed with an integrated magnitude of +11.1, a 150mm instrument sees it as a slightly elongated glow. A 250mm scope reveals an object approaching 2 arcminutes in length and 1 arcminute wide under dark-sky conditions. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**



NGC 669
NGC 708
NGC 679
NGC 753
IC 171
M33
NGC 604
UGC 1281
NGC 750/751
NGC 736
TYC2308-585-1
NGC 777
NGC 769
TYC2308-878-1
Rasalmothallah
NGC 661
NGC 670
NGC 672
IC 1727
NGC 684
Collinder 21
NGC 784
HIP 9493
NGC 890
TRIANGULUM
01h30m
02h00m
+35°
+30°
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AT A GLANCE How the Sky Guide events will appear in October

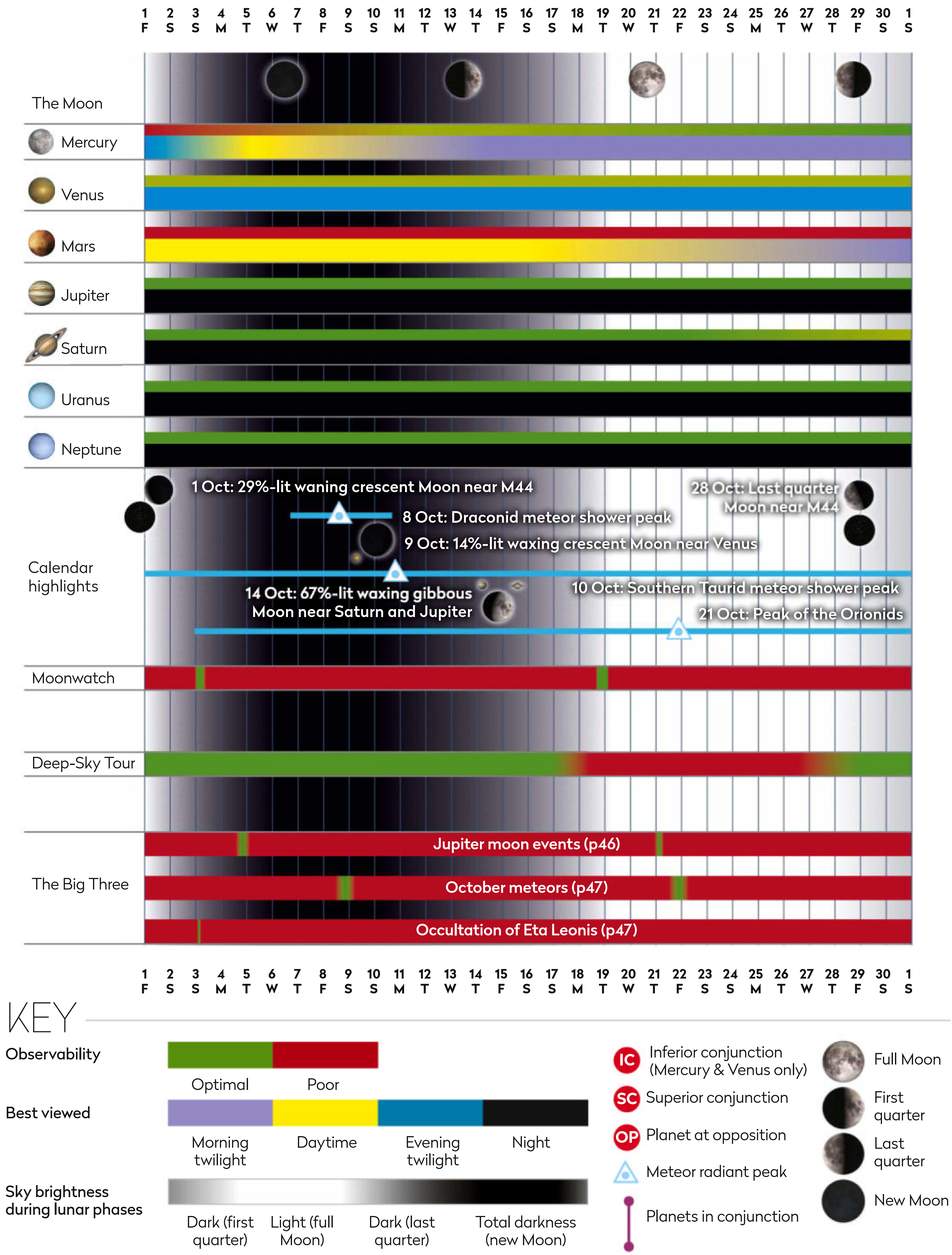

CHART BY PETE LAWRENCE


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As the nights draw out, it's a wonderful opportunity to get more familiar with the starry delights of the new season

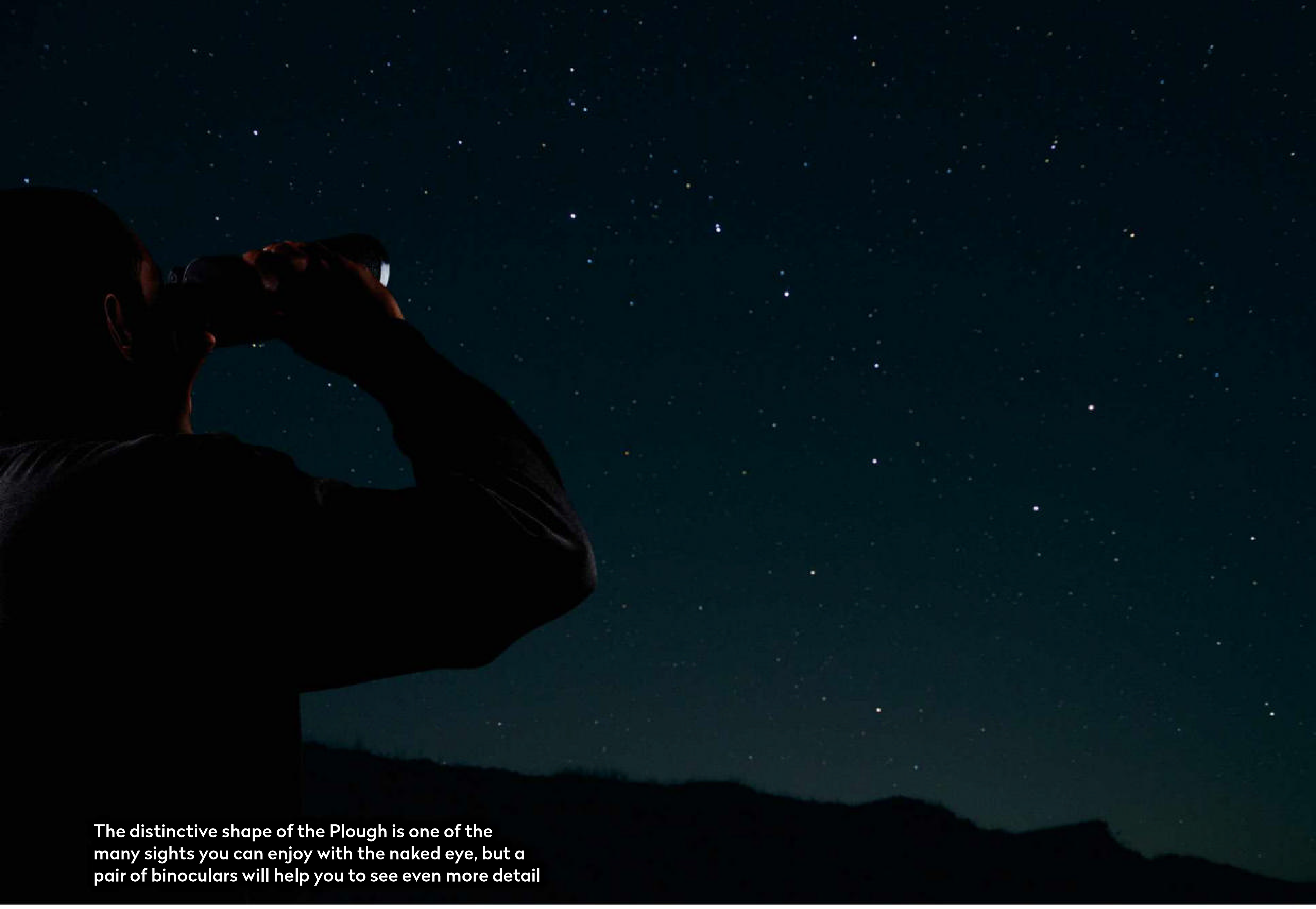
The autumn GRAND TOUR

As the nights begin to get longer, **Stuart Atkinson** takes us on a tour of the new season's astronomical highlights

Stargazers always feel a sense of relief and almost liberation when autumn returns. During summer the night sky doesn't really get dark enough to see all but the brightest stars and deep-sky objects, so after covering up our telescopes we spend the summer months in a kind of enforced astronomical hibernation, watching the lantern-bright International Space Station arc silently across the sky and picking out a bright planet or two on endless twilight nights while crossing our fingers for the northern sky to be painted with a display of noctilucent clouds. But as summer recedes there actually is an 'after dark' again, and a lovely selection of stars, globular clusters, galaxies and other beautiful celestial sights slowly comes back into view. Here we're going to look at some of the best sights to see in the night sky this autumn and how to find them.

Much the same as the Voyager probes famously went on a Grand Tour of the outer Solar System in the 1970s and '80s, moving from planet to planet, with this feature newcomers to sky-watching and experienced amateur astronomers alike will be able to embark on their own – rather quicker – Grand Tour of the wonders of the night sky in celebration of this season. So let us star-hop from constellation to constellation and visit one fascinating deep-sky object after another. ▸

MARK FERGUSON/ALAMY STOCK PHOTO



The distinctive shape of the Plough is one of the many sights you can enjoy with the naked eye, but a pair of binoculars will help you to see even more detail

Preparation is key

Before you head outside there are a few things you need to do. First and perhaps most importantly of all, you need to find a good observing site. Yes, you'll be able to see some stars from your garden, but unless you live on a remote Scottish island, or in the middle of ghost-haunted moorland, your view of the sky will be both blocked by neighbouring properties and affected, perhaps even ruined, by light pollution from surrounding streetlights, external security floodlights on buildings and the illuminated signs of shops and pubs. You'll want to find a spot nearby with as little light pollution as possible, and with as big a view of the sky as possible, and then you'll be set to enjoy your own Grand Tour. Just be sure to stay safe, to stargaze with others where possible and to take heed of any COVID-related restrictions that happen to be in place.

Of course, you might already have a good observing place: a farm gateway or layby that's just up the road from where you live, a car park on the outskirts of town, or maybe a nearby beauty spot – but if you don't then you'll need to do some research. Google Maps or Google Earth are useful for helping stargazers to find good observing sites. If you can, go and check out your site during the daytime, then you won't be caught out by any tall trees, buildings or hills that aren't obvious on the online maps and would spoil your view on a clear night.

Also, it's very important to dress warmly. Autumn nights can feel very chilly and damp, especially after you've got used to the long, shorts-and-sandals nights of summer, so retrieve the gloves, hat, scarf and warm jacket you threw into the back of the wardrobe at the end of spring and snuggle back into them again before going out.

"You won't need a telescope to see the objects featured in this tour, they are all visible to the naked eye"

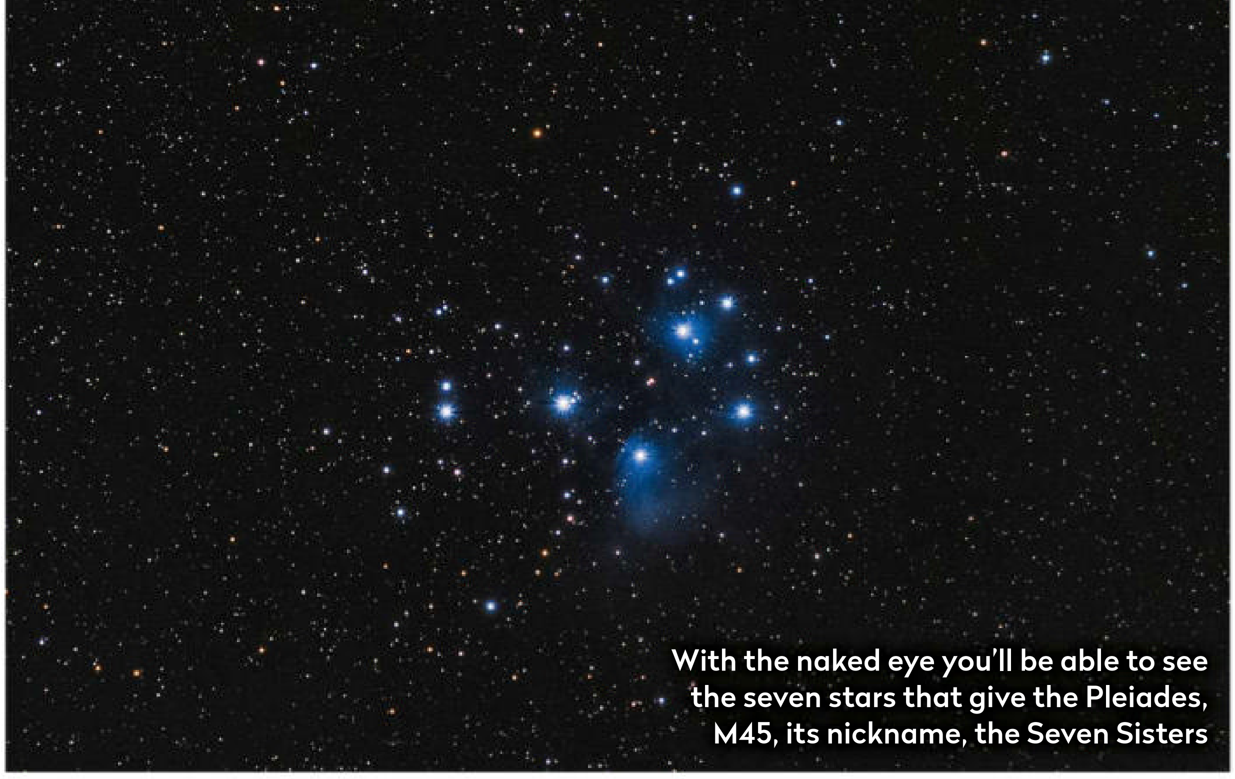
As for equipment, you won't need a telescope to see the objects featured in this tour, they are all visible to the naked eye. However, if you have a pair of binoculars then take those along; they'll give you better views of the objects once you've found them, and ensure you get the most enjoyment from your trip out to a dark sky.

Finally, plan your tour timetable. You'll want to be at your observing site by around 8:30pm, just as it's getting properly dark, so take into account the time it will take you to get there when you make your plans, especially if you're meeting up with other people.

And so, preparations complete, let's begin the Grand Tour...

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books

Looking east



With the naked eye you'll be able to see the seven stars that give the Pleiades, M45, its nickname, the Seven Sisters

The Pleiades

We start our tour by looking low in the sky, just above the northeastern horizon. There you will see – as long as there are no trees, hills or buildings in the way – a knot of blue-white stars, roughly the size of your thumbnail held at arm's length. This is one of the most famous star clusters in the sky: the Pleiades.

This beautiful spill of stars – which is only 444 lightyears from Earth, making it one of the closest star clusters to us – is famously known as The Seven Sisters because, although it contains many hundreds of stars, its seven brightest members can be seen with the naked eye, looking like a miniature version of the Plough. If you have binoculars you will be able to see many dozens of fainter stars dotted around the brightest ones. Whenever stargazers see the Pleiades for the first time in autumn, they know that winter isn't far away. Then the Pleiades will shine high in the sky all through the night, above and to the right of Orion.

The Double Cluster

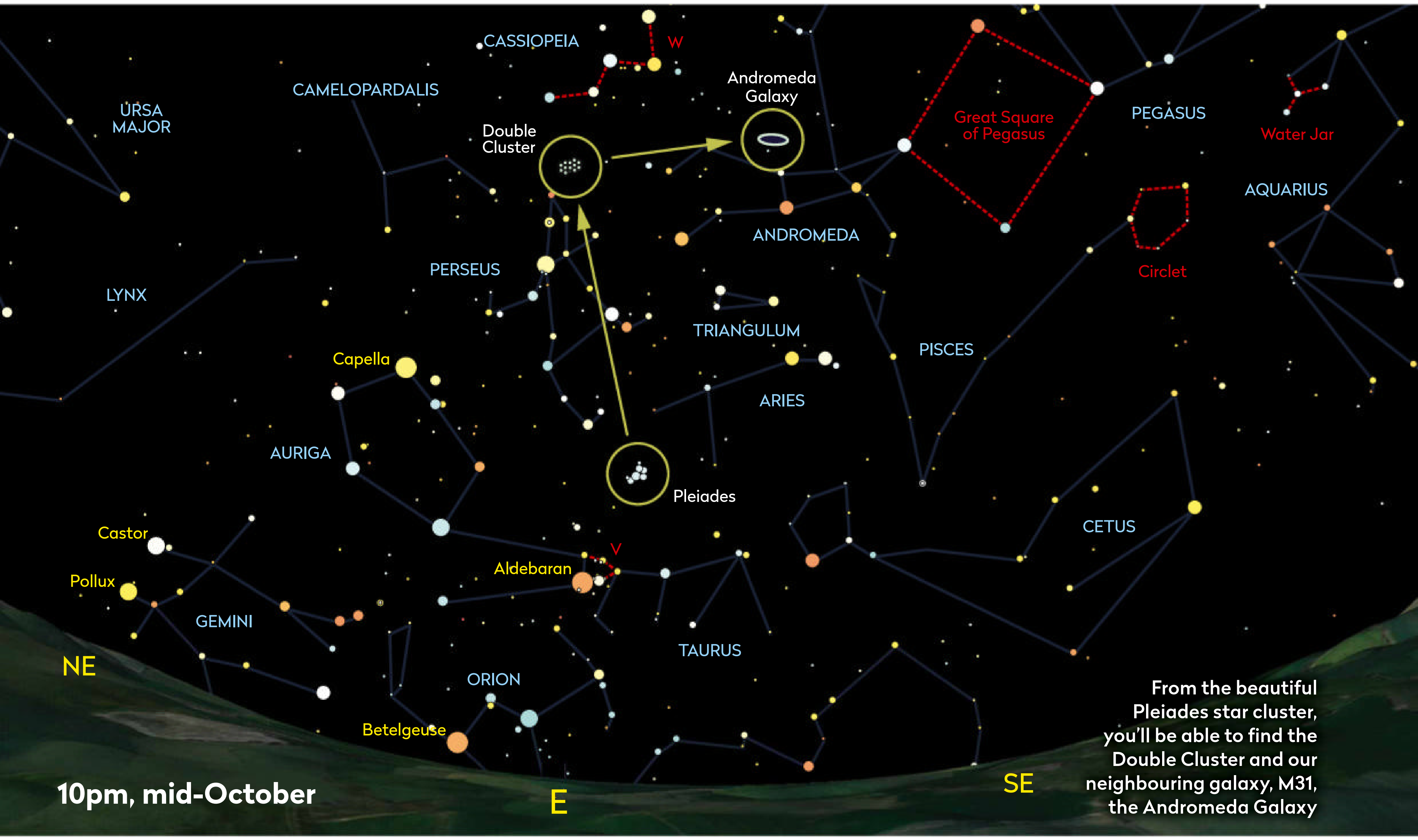
Look to the upper left of the Pleiades, halfway between the 'W' of constellation Cassiopeia, the Queen and the upside down 'Y' of Perseus, the Hero and you'll see a vague, smudgy... something out of the corner of your eye. This is actually two star clusters (NGC 884 and NGC 869) sparkling together side by side, known, appropriately, as the Double Cluster.

Through your binoculars the Double Cluster will be resolved into two distinct star clusters, looking like piles of salt or sugar grains, so close they are almost touching. The clusters are a gravitationally bound pair. Around 8,100 lightyears away, they are separated by a few hundred lightyears.

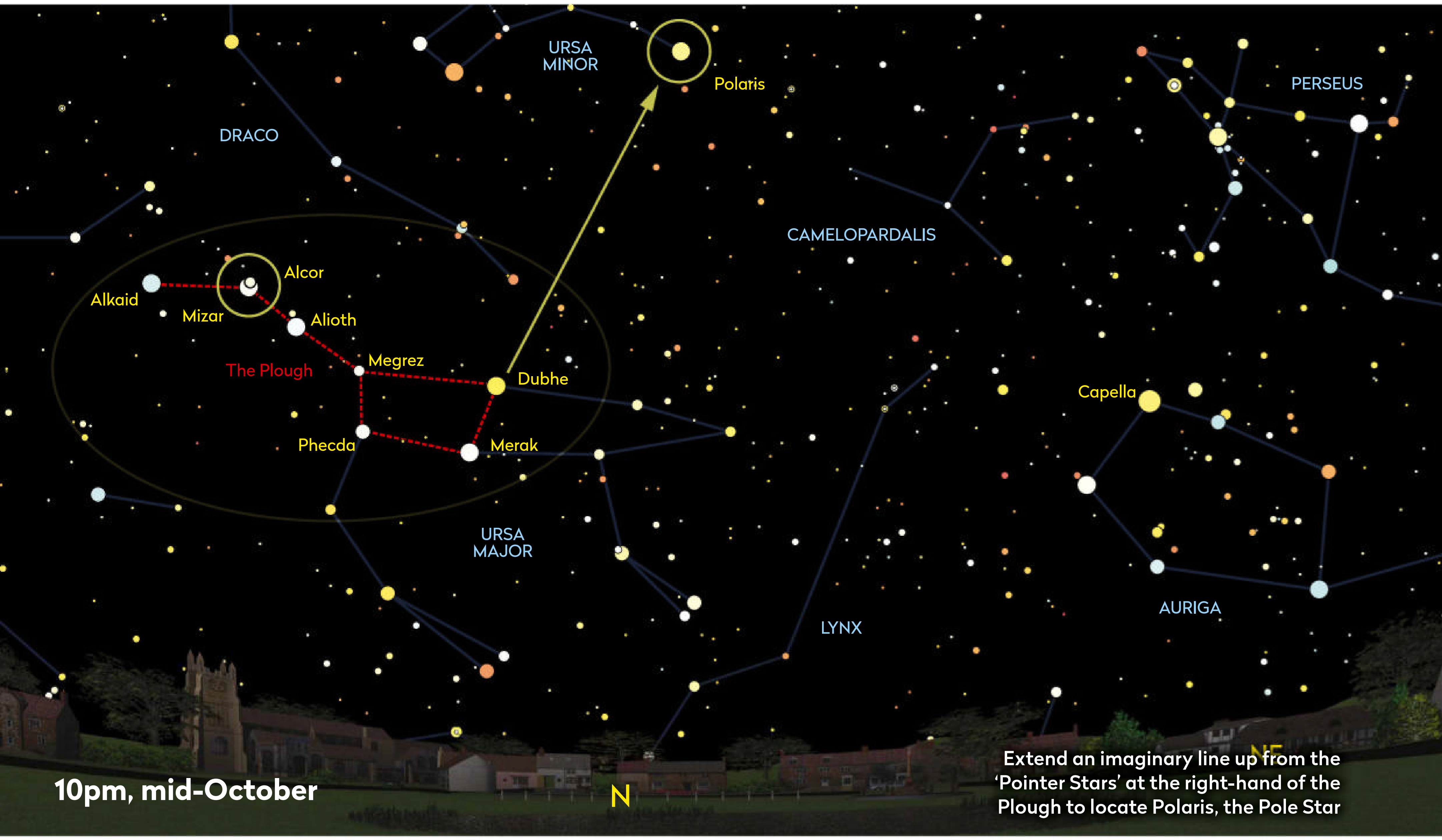
The Andromeda Galaxy

Look to the right of the Double Cluster, approximately halfway between it and the Great Square of Pegasus and you'll see a large, misty smudge with a roughly oval shape. This is M31, the Andromeda Galaxy, a huge spiral galaxy.

M31 is the closest spiral galaxy to our Milky Way, but it's still so far away that its light takes around 2.5 million years to reach us. This makes M31 famous in astronomy as a distant object that is visible to the naked eye. Through your binoculars M31 is revealed to be a lens-shaped haze of light, noticeably brighter in the centre, that covers an area of night sky that's roughly six times as large as the full Moon. ▸



From the beautiful Pleiades star cluster, you'll be able to find the Double Cluster and our neighbouring galaxy, M31, the Andromeda Galaxy



10pm, mid-October

Extend an imaginary line up from the 'Pointer Stars' at the right-hand of the Plough to locate Polaris, the Pole Star

Looking north

The Plough

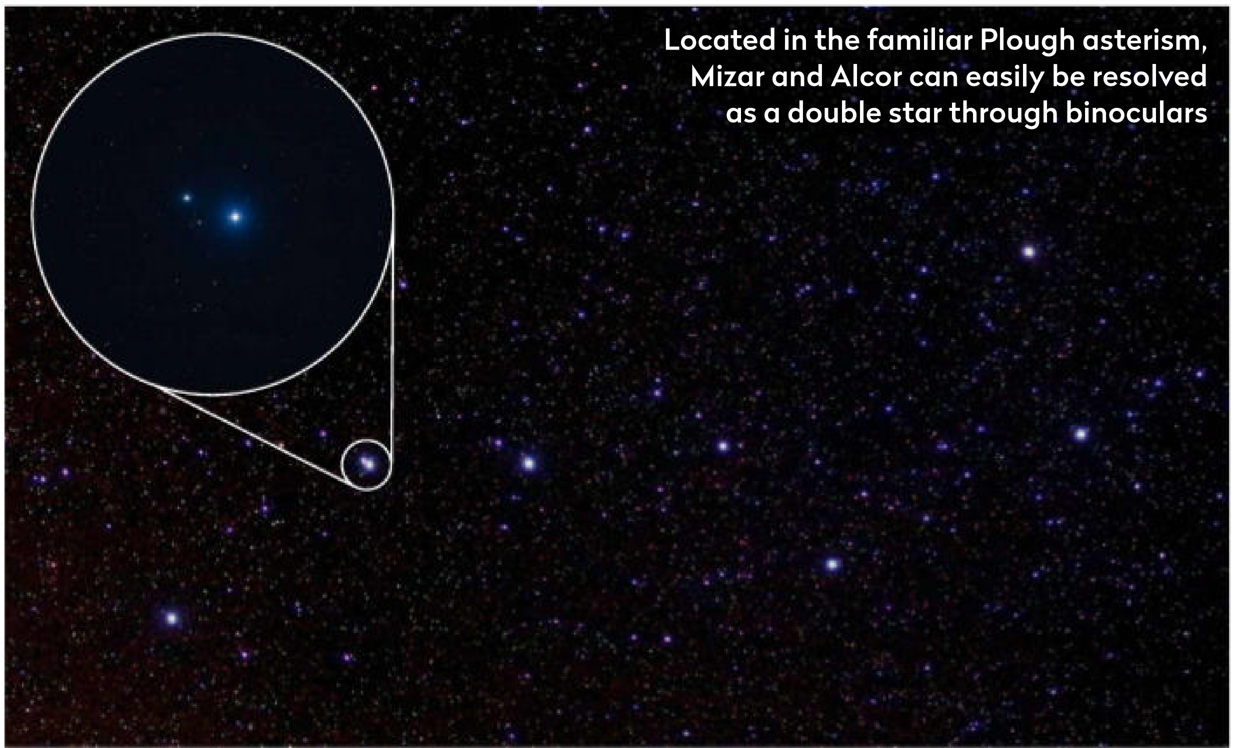
Look just above the northern horizon and you'll see a pattern of stars that will remind you of a large saucepan. This is the famous Plough, or Big Dipper, one of the most easily recognised patterns of stars in the sky – but you might be surprised to learn that it's not a constellation. The Plough is an asterism, a pattern of stars obvious to the eye that forms part of an actual, larger constellation. The stars of the Plough are part of the constellation Ursa Major, the Great Bear, and represent its hindquarters and tail. Autumn is a very good time of year to see the Plough because it lies parallel to the horizon as darkness falls, and it is in the orientation most people expect it to be.

Mizar and Alcor

If you have reasonably good eyesight and look closely at the star Mizar, (Zeta (ζ) Ursae Majoris) positioned halfway along the curved handle of the Plough, you'll see it's not one star but two, shining very close together. Mizar's fainter companion is called Alcor (80 Ursae Majoris), and together these two stars are one of the most famous double stars in the whole of the night sky. They were used as a test of eyesight in years gone by. If you can't split them with your naked eye then don't worry, as your binoculars will show it.

Polaris

Ask any of your non-astronomer friends to name a star and most will quickly answer the 'Pole Star' or 'North Star' and a few might even know its official name, Polaris. This is because many people have grown up believing it is the brightest star in the heavens, but this isn't true. Polaris (Alpha (α) Ursae Minoris) might be the brightest star in Ursa Minor, the Little Bear, but it is only the 48th brightest star in the sky, about as bright as the stars that make up the nearby Plough, so it doesn't really stand out in the night sky at all. It's only important because it happens to lie almost directly above the polar axis of Earth, which means all the other stars, their constellations and everything else in the sky appear to rotate around it as Earth spins. Finding it is easy: just go back to the Plough and draw an imaginary line upwards from the two stars known as 'The Pointers' – that line will take you to Polaris.



Located in the familiar Plough asterism, Mizar and Alcor can easily be resolved as a double star through binoculars

STUART ATKINSON X 2, ALAN DYER/STOCKTREK IMAGES/GETTY, CHARTS BY PETE LAWRENCE

Looking west

Hercules Globular Cluster

Look just above the western horizon after dark on early autumn nights and you'll see a small rectangle of stars, squashed in at the bottom. This is an asterism known as The Keystone of Hercules and if you look a third of the way down on its right side you'll see what looks like an unimpressive, out of focus star. Binoculars will show it more clearly, but will still only resolve it into a round smudge of light. This is M13, a condensed mass of several hundred thousand stars, forming a huge ball or globe of suns known as a globular cluster. It is around 23,000 lightyears away.

Deneb

Deneb (Alpha (α) Cygni), the brightest star in the constellation of Cygnus, the Swan, lies to the upper left of M13, past the bright star Vega (Alpha (α) Lyrae). Marking the head of the asterism known as the Northern Cross, it is one of three bright stars which form another asterism, the Summer Triangle.

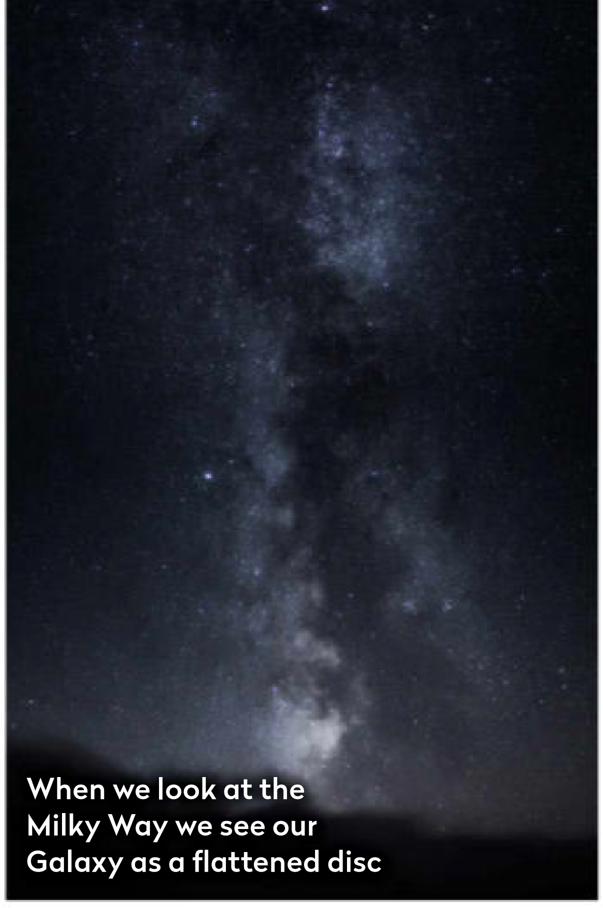
Deneb is a true giant among the stars, 200 times bigger than our own Sun. It is very powerful too, about 200,000 times more luminous than the Sun, and even though it is over 2,600 lightyears away it is the 19th brightest star in the night sky.

If you look at Deneb through binoculars you will see it is surrounded by countless thousands of fainter stars, thick as pollen grains. This is because it is embedded in...

The Milky Way

To end our tour, look to the western horizon and then slowly tilt your head back. If your eyes are properly adapted to the dark you'll see what looks like a broad band of pale light rising up from the west and arcing over your head. This is the Milky Way.

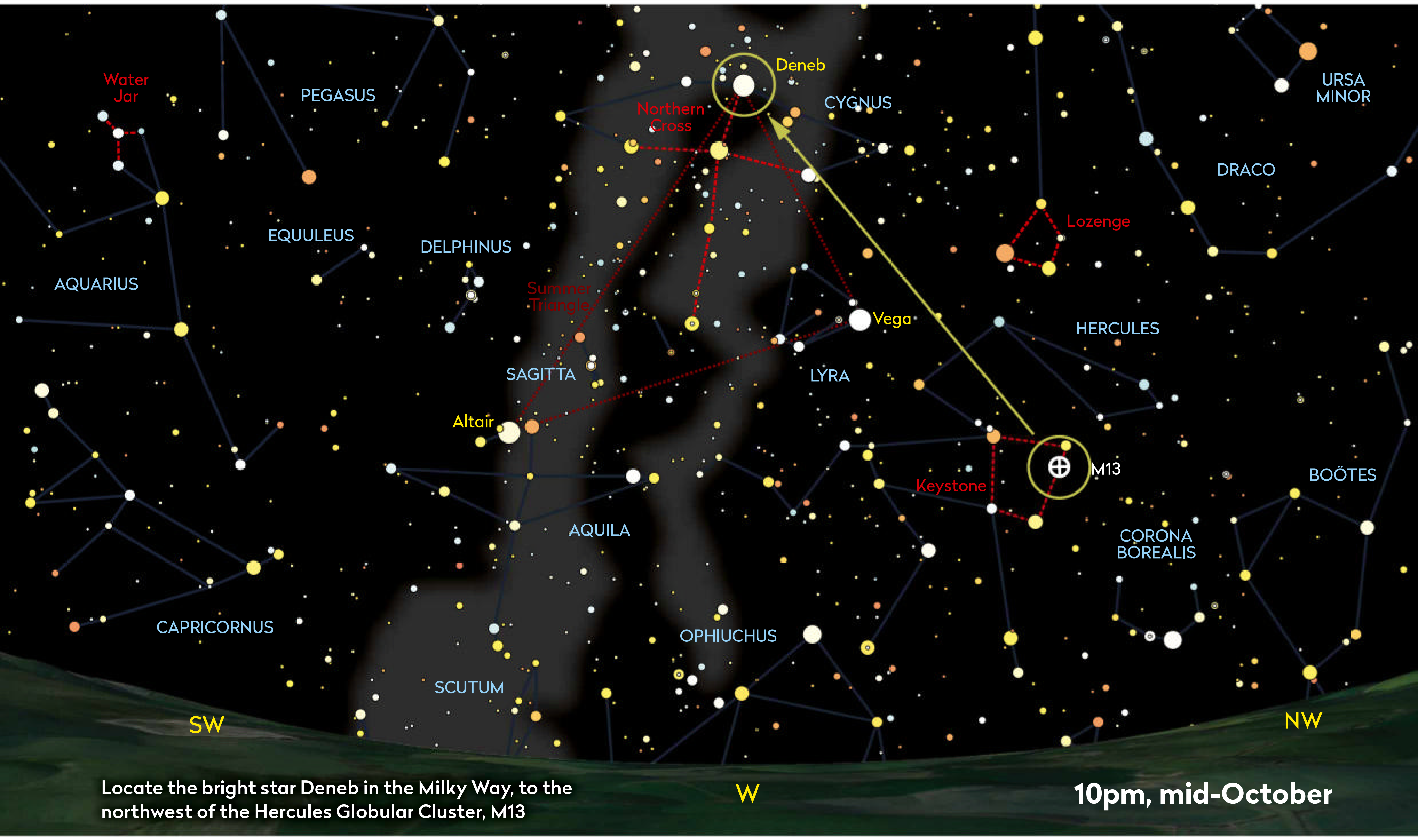
Many observers compare the Milky Way's naked-eye appearance to a plane's vapour trail or smoke rising up from a distant campfire, but if you look at it with your binoculars you'll see it is the combined glow of countless billions of faint, pinprick stars. Sweep along the Milky Way with your binoculars and you'll see knots, clumps and trails of stars embedded within it. In some places, such as down the right side of the Northern Cross, the stars are so plentiful they form star clouds that look like they have been sprayed on the sky with an airbrush.



When we look at the Milky Way we see our Galaxy as a flattened disc

When you look at the Milky Way you're looking at our own Galaxy from the inside. It's a huge spiral of billions of suns, but because we're inside it we can't see its curving spiral arms. What we see instead, looking through its flattened disc, is a band of light – which ancient sky-watchers named the Milky Way because it looked like milk sprayed across the sky.

Our Grand Tour complete, we can look forward to the coming months as the nights get even longer and darker, and a new astronomy season is upon us.



Locate the bright star Deneb in the Milky Way, to the northwest of the Hercules Globular Cluster, M13

HUBBLE OUT OF TROUBLE

The venerable space telescope spent weeks out of action this summer. **Melissa Brobby** looks at how NASA brought it back to life and asks how long Hubble has left

Scientists around the world breathed a sigh of relief on 15 July. After a nervous few weeks, NASA had returned the Hubble Space Telescope's science instruments to operational status, and science data collection was able to resume for the first time since the space telescope stopped working in mid-June.

The nerves were understandable: since deployment in April 1990, Hubble has been one of the most productive scientific instruments ever built. It has made over 1.3 million observations, contributing data for more than 18,000 published scientific papers on a broad range of topics from black holes to planet formation. Astronomy textbooks include contributions from the orbiting space observatory, and Hubble's discoveries and memorable images have ignited the public's fascination with space over its 31 years in orbit. But is Hubble now starting to show its age? Are its components just too old? And is the launch of the James Webb Space Telescope this November coming at just the right time?

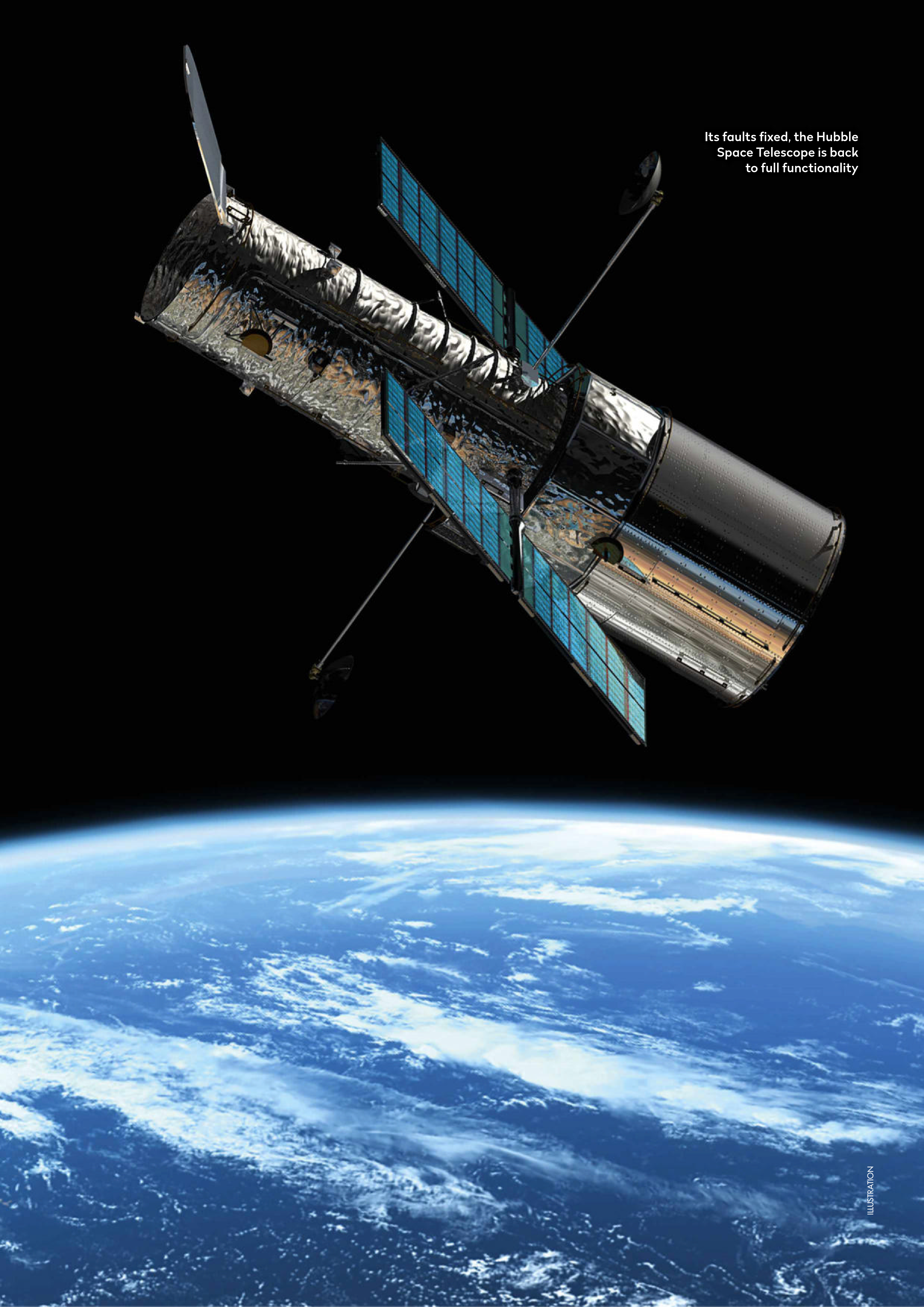
"Since deployment in April 1990, Hubble has been one of the most productive scientific instruments ever built"

First, let's go back and look at what Hubble's issue was. The short answer is its payload computer went wrong. This sits in the Science Instrument Command and Data Handling (SI C&DH) unit on board the telescope and controls, monitors and coordinates Hubble's science instruments. On 13 June, the payload computer suddenly stopped working and it was unable to send its regular signal to the main computer, telling it all was well. Because of this, the main computer placed all science instruments in safe mode and suspended the telescope's observations.

The Hubble team had to move swiftly to work out the cause of the halt and fix it. But fixing a telescope built in the 1980s and orbiting 550km above Earth needed the help of those who have worked on it over its 30-plus year history, and original paperwork dating back up to four decades.

Hubble has backup modules but switching to these did not resolve the issue. So a series of tests – including attempts to restart and reconfigure the main and backup computers – were carried out and, although these were also unsuccessful, results from them ▸

ESA



Its faults fixed, the Hubble Space Telescope is back to full functionality

ILLUSTRATION

The Hubble Space Telescope was deployed from the Space Shuttle Discovery on 25 April 1990

▸ showed that the possible cause of the issue was the Power Control Unit (PCU), designed to supply a steady voltage to the payload computer's hardware. Addressing these issues would add additional risk, as switching to these components' backup units would mean switching several other hardware boxes too.

More than 50 people went through the procedures to switch to backup hardware, testing them on a simulator. On 15 July, the team planned the switch to the backup SI C&DH unit, which contains a backup of the PCU. Around 15:30 UT, the team declared the switch successful and the science instruments were bought back to operational status, allowing Hubble to begin taking scientific data again.

Early problems

Alongside the discoveries and breathtaking images, Hubble has not been free from problems since it started circling Earth. Designed to be serviced in orbit, the space telescope was built with modular components that astronauts could handle and replace easily, and Hubble could be fitted with new science instruments and other equipment during servicing missions, which lasted from 1993 to 2009.

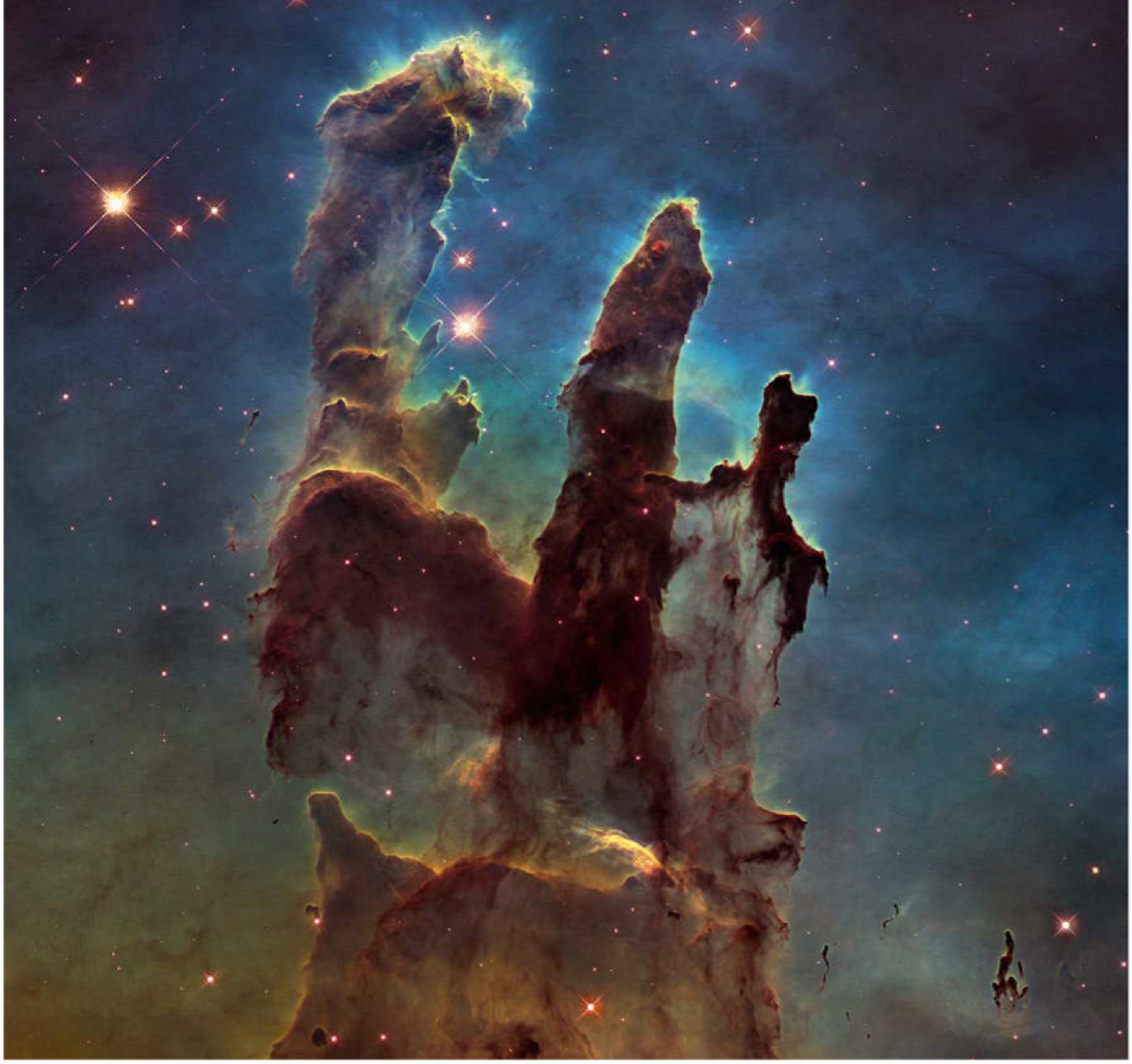
But these couldn't help with the major fault that was discovered just after launch in 1990, when it was immediately apparent that its images were blurred. The fault was traced to Hubble's primary mirror which had been ground precisely, but to the wrong shape. Astronauts were sent on the first servicing mission in December 1993 with replacement instruments that fixed the flaw, allowing Hubble to capture such famous images as 'The Pillars of Creation'.

The second service mission took place in February 1997 to replace degrading spacecraft components and install the Space Telescope Imaging Spectrograph (STIS), and Near Infrared Camera and Multi-Object Spectrometer (NICMOS) instruments. The STIS separated light taken in by the scope and spilt it so the composition, temperature, motion and other properties could be analysed; while the NICMOS allowed scientists to see clear views of the Universe

▲ Above left: Hubble's primary mirror was ground in 1979, but minute defects remained undiscovered until the space telescope had been placed in orbit over a decade later

Above right: When the mirror was repaired in 1993 the difference in image quality was immediate and dramatic, as these two images of the core of galaxy M100 demonstrate

▸ 'The Pillars of Creation', one of Hubble's most iconic images, of the heart of the Eagle Nebula, was captured twice. This version (right) was released to mark the space telescope's 25th anniversary in 2015



at near-infrared wavelengths for the first time.

Then in November 1999, the fourth of Hubble's six gyroscopes failed. The gyros measure Hubble's rate of motion and help the telescope point towards its observation targets, and it needs three to be working to make observations. This led to Hubble going to sleep while a fix was awaited. So the third servicing mission, originally a maintenance mission, was spilt into two parts: Servicing Mission 3A flew in December 1999 to replace all six gyroscopes; and in March 2002 Servicing Mission 3B replaced solar panels and installed the Advanced Camera for Surveys (ACS), taking the place of the Faint Object Camera, which was the telescope's last remaining original instrument.

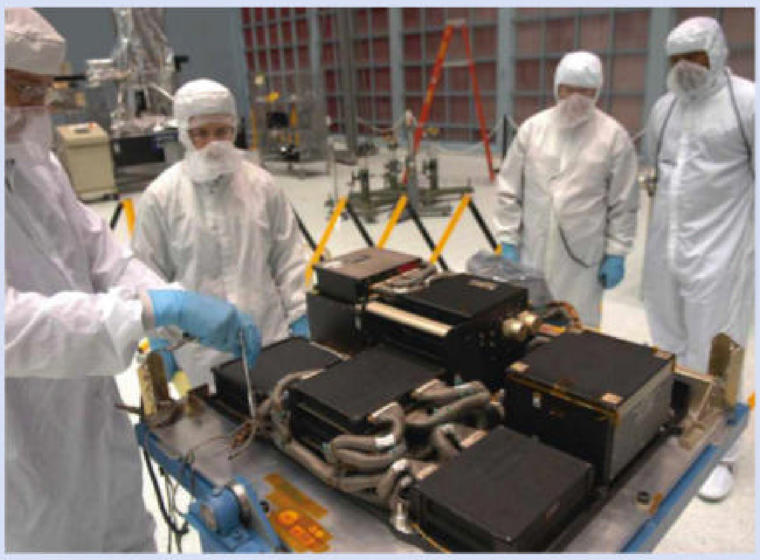
During Hubble's fourth servicing mission in May 2009, astronauts performed the first ever in-orbit repairs on the STIS and ACS, which had both failed. Along with new batteries, new gyroscopes and a new ▸

Computer says no

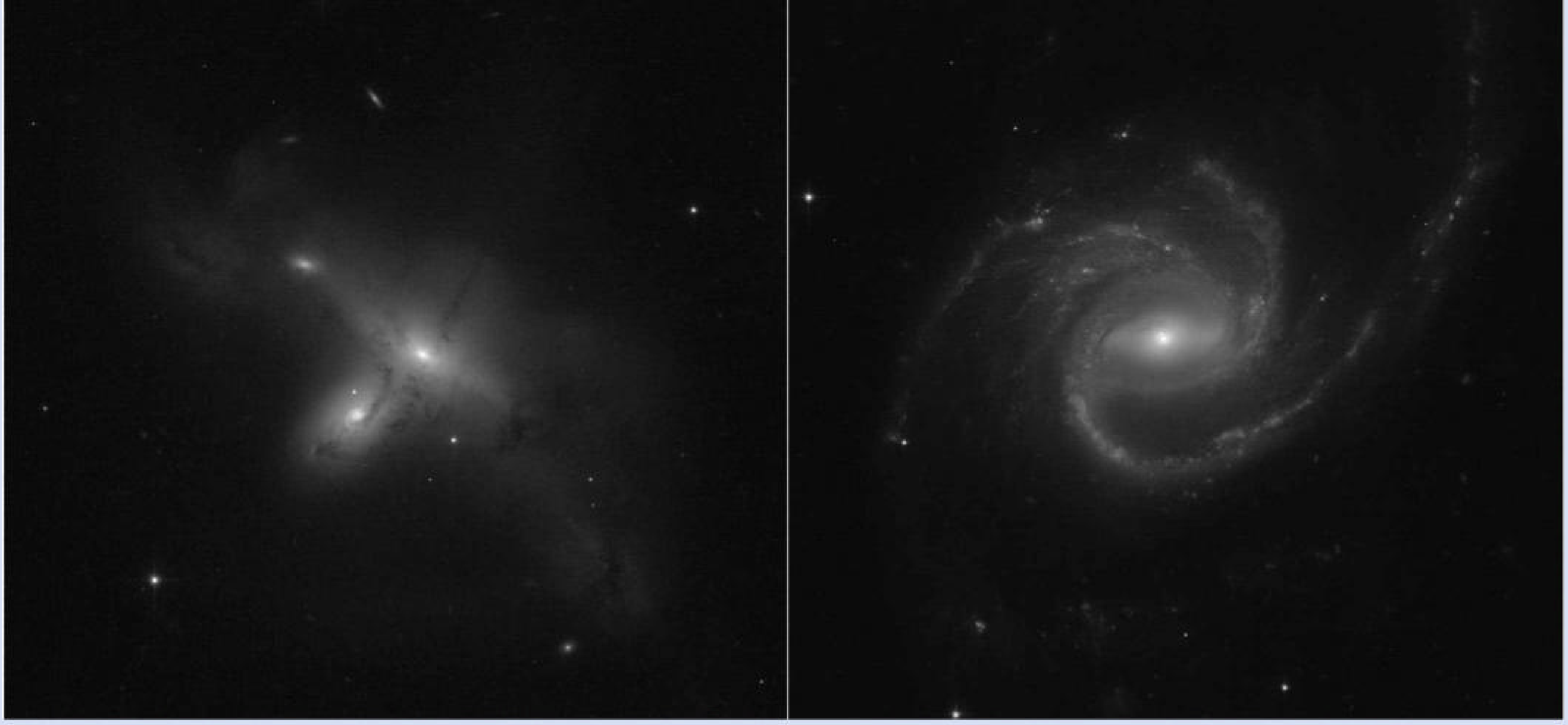
The unit that led to Hubble's outage in June was a vintage computer component

Hubble's payload computer is a NASA Standard Spacecraft Computer-1 (NSSC-1) system, which sits in the Science Instrument Command and Data Handling (SI C&DH) unit. Hubble's NSSC-1 system was built by IBM in the 1980s but the original design, which was developed at the Goddard Space Flight Center as a standard component for the MultiMission Modular Spacecraft, dates back to 1974. It was developed as part of a set of modules and components that would help reduce costs, and was used on the Landsat 4 and Landsat 5 missions, the Solar Maximum Mission and other missions mainly limited to the Solar System, including the Gamma Ray Observatory and the Upper Atmosphere Research Satellite.

NSSC-1's purpose is to control and coordinate the science instruments onboard Hubble, monitoring them for health and safety. Hubble has two payload computers, one of which serves as a backup that can take over in the event of a problem. Both computers have access to any of the four independent memory modules, which each contain 64K of core memory. The payload computer uses only one memory module at a time while the other three serve as backups.



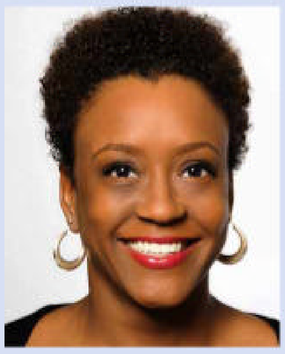
▲ Technicians prepare the replacement SI C&DH for testing at the Goddard Space Flight Center in 2009



▲ Images of galaxies ARP-MADORE2115-273 (left) and ARP-MADORE0002-503 (right) from July 2021 showed Hubble was back in order

Keeping an eye on Hubble

Meet Nzinga Tull, Hubble Systems Anomaly Response Manager



What does your role at NASA involve and how long have you been in it for?
One of my primary roles is as an Anomaly Response Manager who uses systems engineering expertise to coordinate anomaly investigations and lead anomaly response and recovery efforts. After 13 years on the Hubble mission operations team earlier in my career, I rejoined the team in November 2018.

How long did the problem with Hubble take to diagnose and how serious was the issue?
Hubble has an extensive, automatic data-monitoring system that sends system engineers 'alert' signals when something goes wrong; so we were alerted immediately when the payload computer first halted on 13 June. There were about two weeks of dedicated anomaly investigations before we began planning to recover the payload by activating back-up components. The meticulous development and testing of the recovery procedures took about 2.5 weeks to complete in parallel with on-going root cause analysis before the on-orbit recovery was attempted.

The issue with the Power Control Unit (PCU) was serious enough to halt the science mission but we still don't know for sure if the issue is permanent.

Is it possible that the same issue with the payload computer could happen again and is there anything that can be done to prevent the problem from recurring?
If it is a transient problem that can be improved, say, if the Power Control Unit sits cold for some time, we may still have some redundant functionality down the road. But, for now, we are prioritising the continuity of the science mission and we will continue to operate Hubble using the backup components.

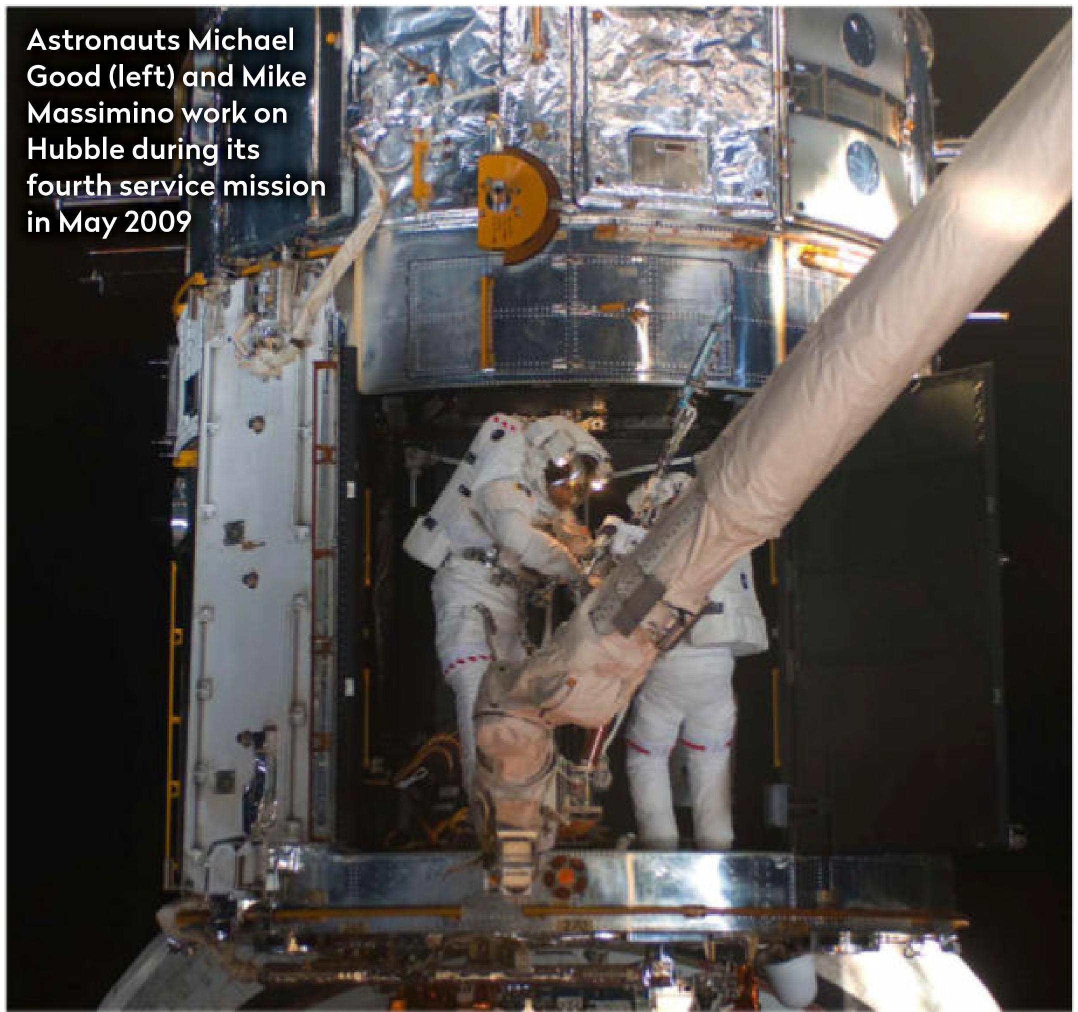
What is next for Hubble now the issue is fixed? How long is the space telescope expected to be in operation for?
Now that payload computer is working again, we have re-started the science instruments and they are back to collecting the amazing images that make Hubble a beloved resource with astronomers and the stargazing public. The systems engineering team will continue to monitor and analyse telescope data to get ideas on how to optimise operations and extend mission life for years to come.

▸ science computer, these replacements played an instrumental part in prolonging Hubble's life.

The problems this June are not the first time that backup hardware has come to Hubble's rescue. In 2008, the Hubble team performed a switch similar to the one that took place recently, when another part of the SI C&DH unit failed. The unit was replaced during the final servicing mission on 11–24 May 2009.

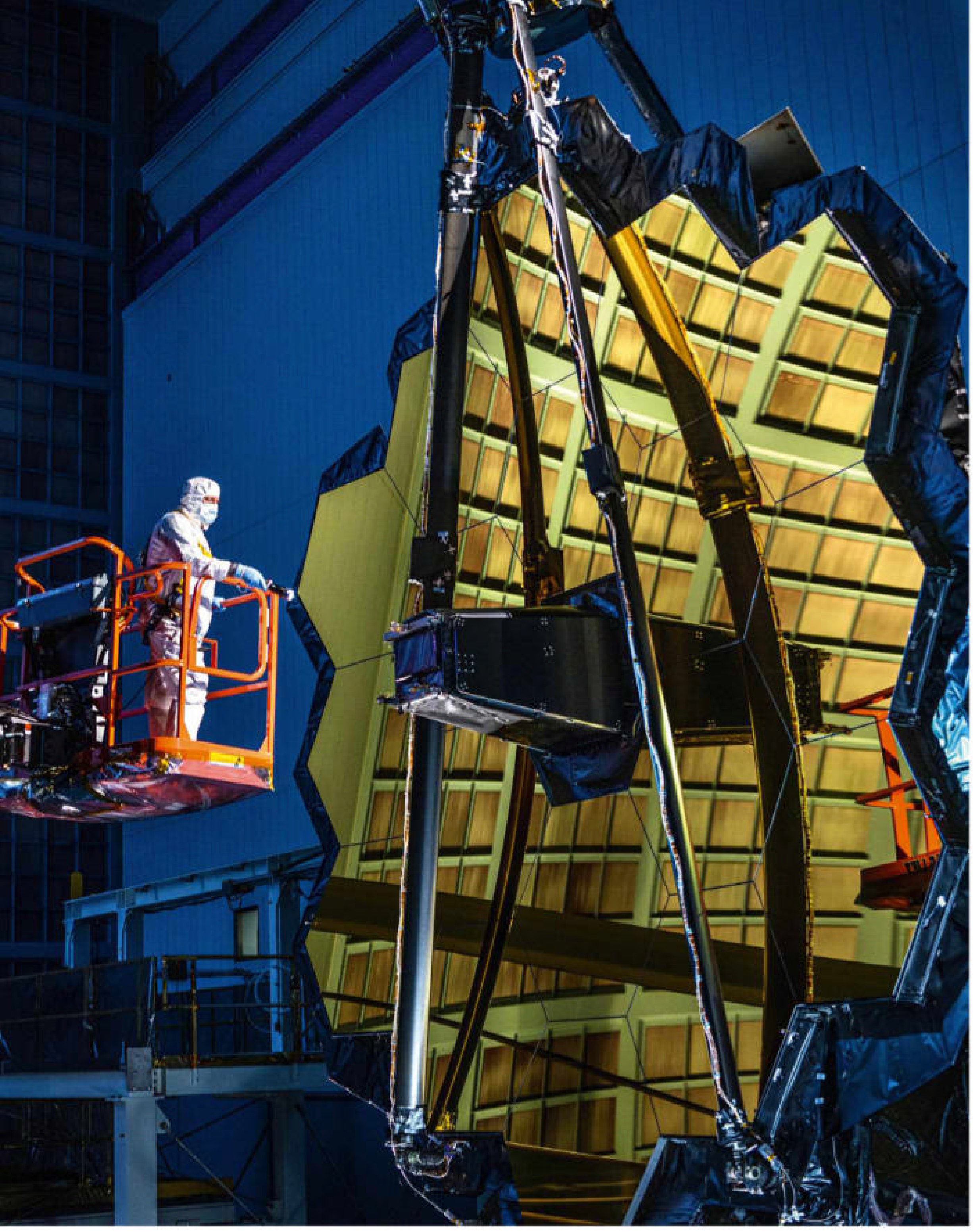
Since the Space Shuttle's retirement, servicing Hubble from the ground was always going to be a challenge, especially as it continued to run into problems after its last servicing mission. In March 2014, one of Hubble's gyroscopes failed, followed by another in April 2018 and the last in October 2018. The operations team activated a backup gyro but, according to NASA, the backup "...incorrectly returned rotation rates that were far in excess of the actual rates," so Hubble was once again placed into safe mode while the problem was fixed on the ground.

The operations team instructed Hubble to perform



Astronauts Michael Good (left) and Mike Massimino work on Hubble during its fourth service mission in May 2009

NASA/ESA/STSC/JULIANNE DALCANTON (UW)/ALYSSA PAGAN (STSCI), KEVIN MCEWENM, NASA, NASA/CHRIS GUNN, NORTHROP GRUMMAN



ILLUSTRATION

◂ **Extensive testing has been conducted on the gigantic 6.5m primary mirror of the James Webb Space Telescope (above)**

"JWST has a much larger 6.5m-diameter primary mirror – huge compared to Hubble's 2.4m mirror"

a series of manoeuvres and switched the gyro between different operational modes to ensure it was stable. Once the team had tested pointing accuracy and target activities without issue, Hubble's scientific instruments were restored to normal operational mode with three functioning gyros.

However, Hubble entered partial safe mode in January 2019 due to suspected hardware issues in its Wide Field Camera 3 (WFC3) unit – the telescope's last and most technically advanced instrument, installed during Hubble's fourth Servicing Mission in 2009. The cause of the failure was found to be a software problem, so the telemetry circuits were reset and the (WFC3) was returned to normal operation.

Now that Hubble's latest issue is fixed, what's next for it? There may not be any in-orbit repairs scheduled, but there is a dedicated team of engineers and scientists working hard to keep Hubble operating for as long as possible. There are currently no set plans for Hubble's retirement; Nzinga Tull, Hubble Systems Anomaly Response Manager at NASA's Goddard Space Flight Center, says the telescope is expected "...to be at or near full functionality through the mid-2020s, at least, and we are considering alternative operational modes so that we can continue a reduced science mission in the future."

While Hubble continues on, the James Webb Space Telescope is getting ready to begin its mission, with a target launch date this year on 31 October. JWST is often referred to as Hubble's replacement, but NASA sees it more as its scientific successor because its capabilities are different. While Hubble studies the Universe at optical and ultraviolet wavelengths, JWST will primarily observe in the infrared.

The JWST has a much larger 6.5m-diameter primary mirror, which is huge compared to Hubble's 2.4m mirror, and it also has a much larger field of view than Hubble's NICMOS camera, covering more than 15 times the area. The JWST will be able to look further back in time than Hubble, giving a glimpse of the birth of the first galaxies. It will look inside dust clouds where stars and planetary systems are forming, and study the atmospheres of exoplanets to see where else the building blocks of life are developing in the Universe.

Lessons learned

Despite a multitude of launch delays, NASA is confident that the lessons learnt from Hubble will prevent the JWST from experiencing the same issues. Destined for a position 1.5 million km from Earth (at the L2 Lagrange point – where the gravitational forces from the Sun and Earth exactly balance the centrifugal force) the JWST is not designed to be serviced by spacecraft. Rigorous testing on the JWST's mirror has taken place before launch, including an alignment check of its 18 gold-plated, hexagonal primary mirror segments to ensure they act like a single mirror – testing that NASA had not done on Hubble before its launch.

The JWST is the biggest and most technologically advanced space telescope built and a lot is riding on its success, especially as its costs have reached about $10bn. Whatever challenges it throws at its team on the ground, it's set to build on Hubble's record and open up a new side to the Universe that will delight astronomers and the public for years to come.

Melissa Brobby is a science communicator and social media lead at the Institute of Physics

The fundamentals of astronomy for beginners

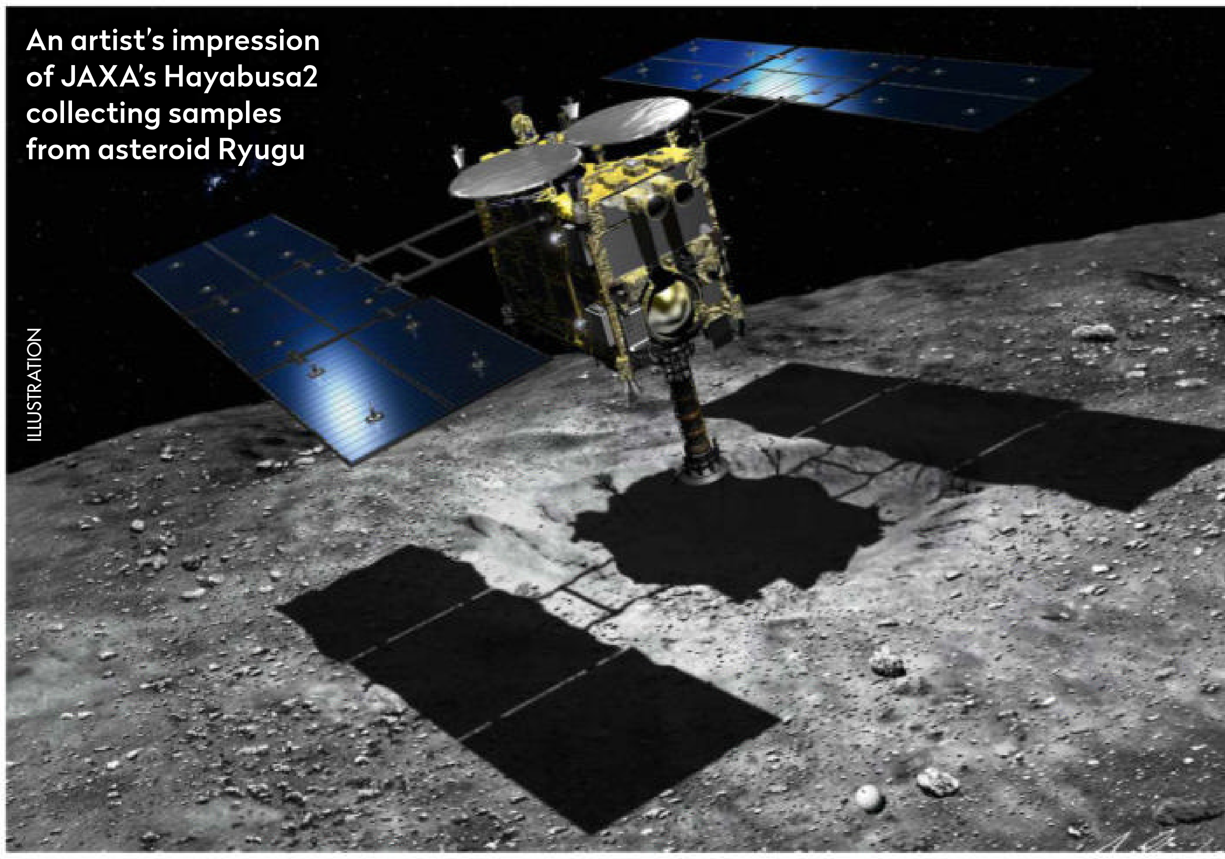
EXPLAINER

What space rocks tell us about the Solar System

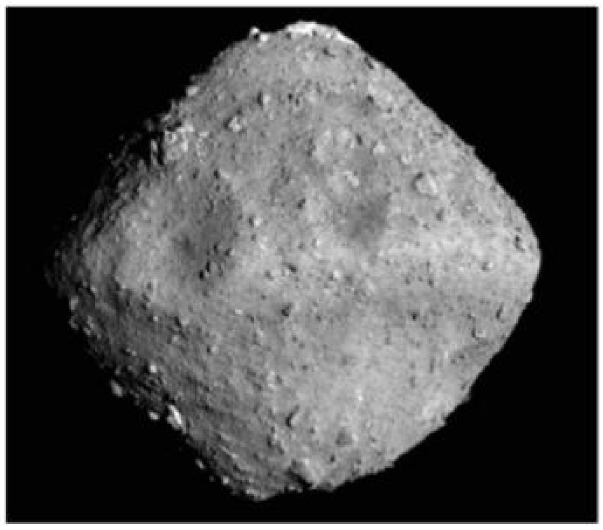
Penny Wozniakiewicz looks at how samples from other worlds are analysed by scientists

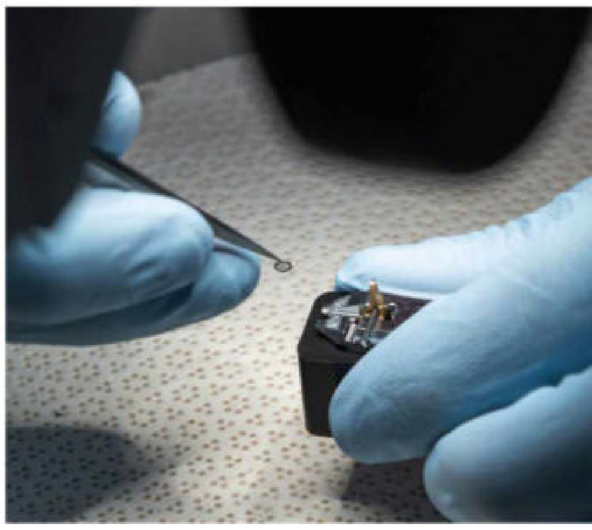
During the early hours of 6 December 2020, JAXA's Hayabusa2 sample return capsule re-entered Earth's atmosphere, streaking across the sky above Southern Australia and landing in the Woomera Test Range. Scientists around the globe were eager to see the precious cargo it carried – samples from asteroid 162173 Ryugu, a C-type or carbonaceous asteroid. C-type asteroids contain large quantities of carbon and water-bearing minerals and are thought to be among the most ancient objects in our Solar System, preserving materials that could help us to understand how the Solar System formed and evolved to become what we see today.

These samples will begin to make their way to members of the Hayabusa2 initial analysis team. One UK group poised to receive samples is led by Professor John Bridges at the University of Leicester. He has studied materials from several of these so-called sample return missions and anticipates that Ryugu will teach us a lot about asteroids, no doubt with one or two surprises along the way. Referring to cometary samples returned by NASA's Stardust mission, Professor Bridges recalls that, "Stardust changed our view of comets – it wasn't just the dusty ice ball we expected. I expect that Hayabusa2 will change our view of C-type asteroids to reveal a rich and detailed history about water and mineralogy in the earliest Solar System."



An artist's impression of JAXA's Hayabusa2 collecting samples from asteroid Ryugu





▲ Above: a C-type carbonaceous asteroid like Ryugu holds clues about mineralogy in the early Solar System

Right: NASA scientists analyse one of the Ryugu samples that has been distributed around the world

Going under the microscope

Given that the Hayabusa2 samples are estimated to weigh in at around 5.4g in total (a massive success considering the aim was just 0.1g), each research group can expect to receive samples consisting of only a few grains. Modern analytical techniques will nevertheless be able to reveal a wealth of information. Professor Bridges and his colleague Dr Leon Hicks (also at Leicester) will use a range of electron microscopes as well as the Diamond Light Source synchrotron facility in Oxfordshire, which acts like a giant electron microscope. By studying the minerals present in the grains, it is possible to make interpretations about the conditions that have existed on Ryugu and hence how it has evolved over time, as each mineral has specific conditions under which it will form. For example, some will only form when there is no oxygen present, some will form under certain combinations of pressure and temperature and some only in the presence of liquid water. Studying the water and organics present in Ryugu is of interest since asteroid and comet impacts could be how such materials were delivered to Earth in the past.

Sample return missions like Hayabusa2 are undeniably useful, providing samples with a known

DEEP SPACE DELIVERIES

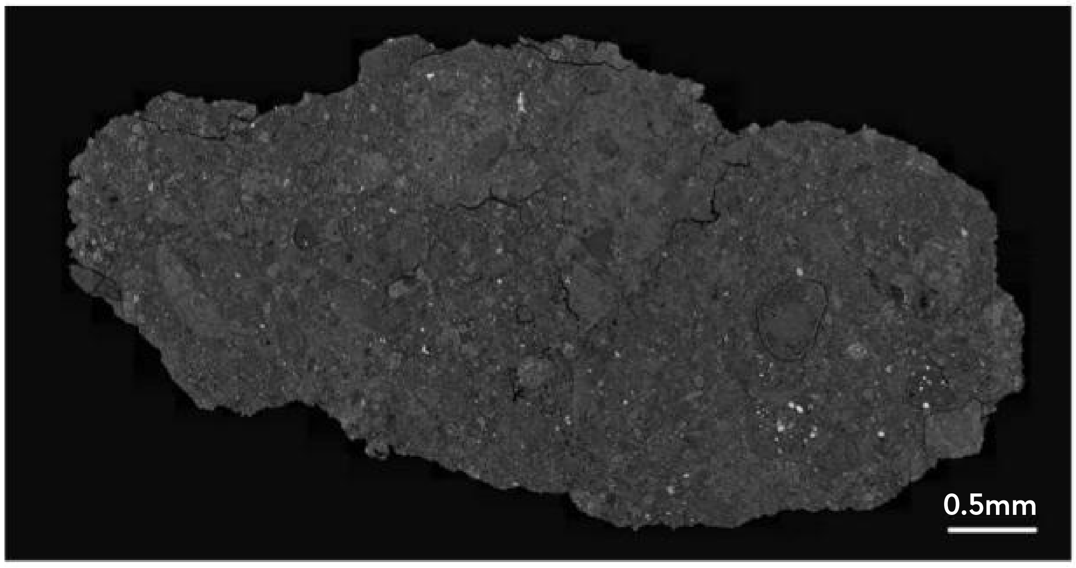
What have we learned from space rocks that have already been returned to Earth?

Lunar: NASA's Apollo and the Soviet Luna programmes returned 382kg and 326g respectively, providing a means to study and date the lunar surface, and date other planetary surfaces based on their crater abundances.

Cometary: NASA's Stardust mission returned samples from comet 81P/Wild in January 2004. The few hundred micrograms collected provided evidence of extensive material transported between the inner and outer Solar System.

Asteroidal: JAXA's Hayabusa mission returned the first asteroid samples from 25143 Itokawa in June 2010. Comprised of less than a milligram of material, they linked chondrite meteorites with S-type asteroids and found water and organics.

Astronaut James Irwin digs into the Moon's surface during the Apollo 15 mission



▲ A cross-section of the Winchcombe meteorite, scanned by an electron microscope at the University of Leicester

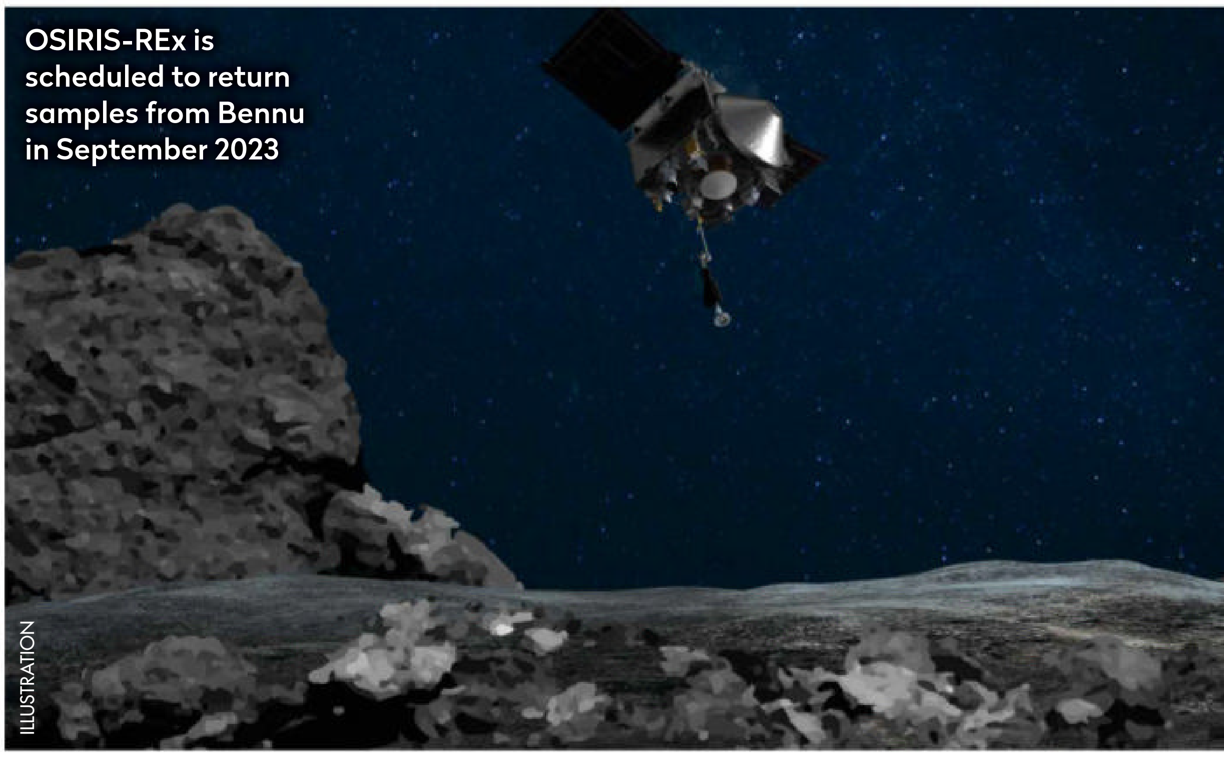
origin and enabling handling after collection to be carefully controlled so that no contamination occurs. However, they are expensive and extremely challenging. Consequently, samples have been returned from only a handful of Solar System objects and Hayabusa2 is only the second sample return from an asteroid.

Winchcombe's space rock

Thankfully, these samples are not the only way we can get up close to asteroids, as most meteorites are also fragments of them. Indeed, carbonaceous meteorites are thought to be samples of primitive C-type asteroids like Ryugu – something to be confirmed by the Hayabusa2 samples. Carbonaceous meteorites represent less than 5 per cent of meteorite 'falls' – those observed to arrive and thus likely collected before they can be contaminated and altered by Earth's rich and active environment. However, as luck would have it, one of these was recently retrieved in the UK – the Winchcombe meteorite, named after the town in Gloucestershire where it fell in February of this year. Around 600g of material was collected and is being analysed at research facilities across the country, including the University of Leicester, providing a further opportunity to probe primitive asteroids and a fantastic sample to compare against material from Ryugu.

Sample return missions look set to make the 2020s an exciting time for planetary science. China's Chang'e 5 returned about 2kg of lunar samples at the end of last year and more C-type asteroid samples are due to arrive in September 2023 from 101955 Bennu thanks to NASA's OSIRIS-REx mission. Further missions to the Moon, asteroids, comets, and even Mars and its satellite Phobos are also being considered for this decade. Added to this, the ever-increasing coverage and popularity of fireball networks like those of the UK Fireball Alliance (UKFAll), and even security cameras and dashcams capable of recording meteors, means we can expect fresh 'fall' samples to be collected more often. These will no doubt result in new discoveries that test existing theories about the Solar System's formation and evolution, and perhaps even our origin, so watch this space as there are fascinating times ahead!

Dr Penny Wozniakiewicz is a planetary scientist and space dust expert based at the University of Kent



OSIRIS-REx is scheduled to return samples from Bennu in September 2023

DIY ASTRONOMY

Make a counterbalance system

Construct a home-built unit that will improve the tracking accuracy of your mount

The completed counterbalance unit...

...and the completed unit in action on a telescope

A well-balanced mount will track to the best of its ability and will improve Go-To accuracy, especially if you are guiding for long exposures on deep-sky objects as it will allow guiding corrections to be made with minimum effort. For an equatorial mount, both the right ascension (RA) and declination (dec.) axes require balancing to avoid overstressing the drive motors and gears in a conventional drive train, or to avoid slippage in a friction drive mount. A balance bar is a simple way of allowing easy and safe balancing of the dec. axis. In this article we will show you how to make your own counterbalance system from readily available components and some basic DIY tools.

Adjusting the balance of the RA axis is simple as it is just a matter of moving the counterbalance weight (or weights) up or down the counterbalance shaft until balance is achieved. However, balancing the dec. axis is more challenging as this entails moving the telescope forwards or backwards in its dovetail clamp. There is also some risk as the clamp that safely holds your scope on to the mount head needs loosening.

With some telescopes, achieving dec. balance conventionally can be difficult or even impossible, especially with the short focal length instruments used with heavier cameras for wide-field imaging.

ALL PICTURES: STEVE RICHARDS

Steve Richards is author of *Making Every Photon Count: A Beginner's Guide to Deep Sky Astrophotography*

This is because many of these instruments are supplied with short dovetail bars that simply don't allow enough movement in the clamp. Add in the complication of a guidescope and the problems begin to multiply; this is where our simple, yet effective counterbalance system comes into its own.

A balanced solution

The concept is straightforward – there's a second dovetail clamp mounted on top of your telescope's tube rings, which has a small counterbalance weight mounted on a long dovetail bar. This slides through the clamp until balance is achieved. A Vixen-style dovetail bar is ideal for this purpose as it's sturdy enough for the task and doesn't contribute too much weight in its own right. Suitable clamps are available from many astronomical suppliers.

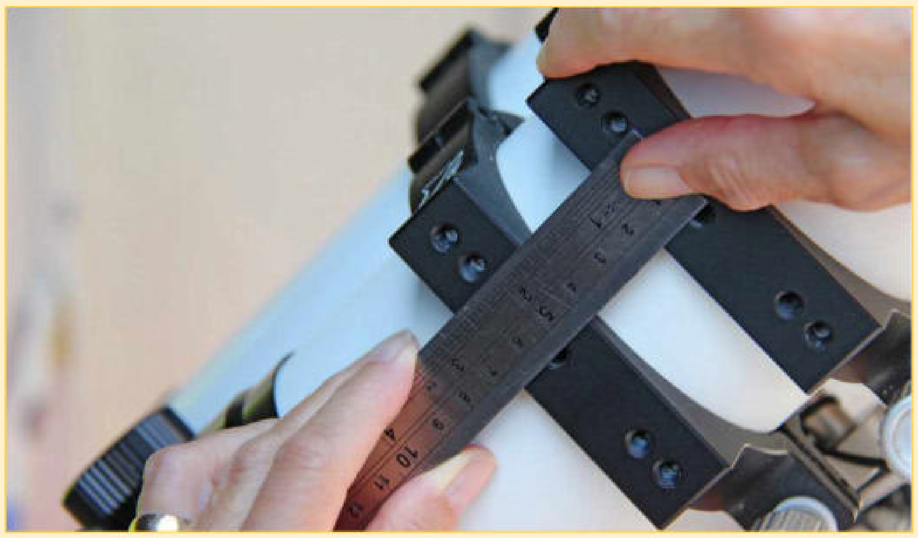
Depending on the telescope and camera or eyepieces that you want to mount and balance, along with the length of the supplied dovetail bar, you may find that additional weight is required at either the front or the back of the telescope. Always try to balance the equipment on the dec. axis as best you can first and make a mark on the dovetail bar and clamp to show the best position for future use. If balance cannot be satisfactorily achieved then this project will come to the rescue as it will allow you to add additional weight to either the front or back.

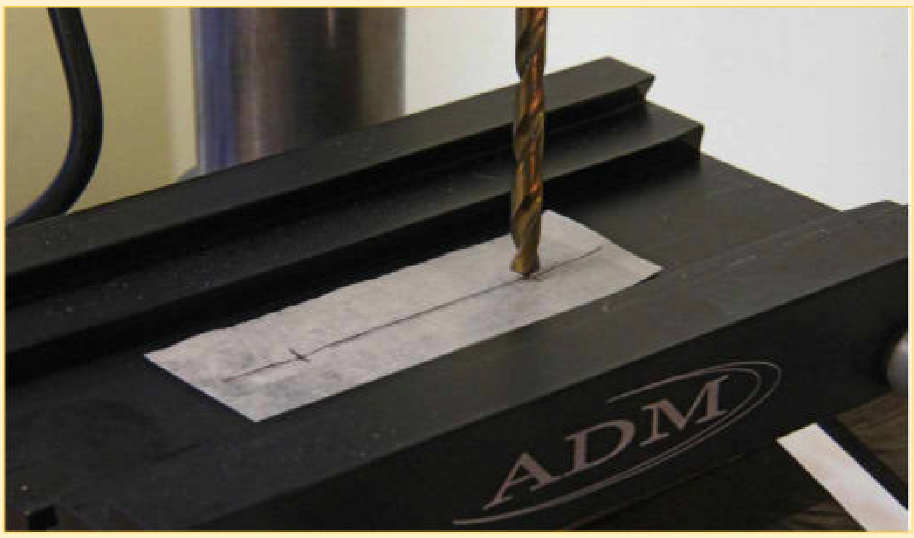
Once the dec. axis is balanced, adjust the RA axis balance by sliding the mount's counterbalance up or down the counterbalance bar. If you are using an autoguider and a gear-driven mount, bias the RA axis to be slightly counterweight-heavy on the 'rising' side.

What you'll need

- A 33.5cm dovetail bar; a dovetail clamp (size suitable for mounting on top of the tube rings); a counterbalance weight; a 6mm bolt that's long enough to pass through the counterbalance weight; a 6mm washer; a large Nyloc nut for use as a spacer; two bolts to attach the dovetail clamp to the tube rings.
- A tape measure or steel ruler; masking tape and a pencil
- An electric drill or pillar drill; a 6mm drill bit and countersink cutter; a 6mm tap tool

Step by step



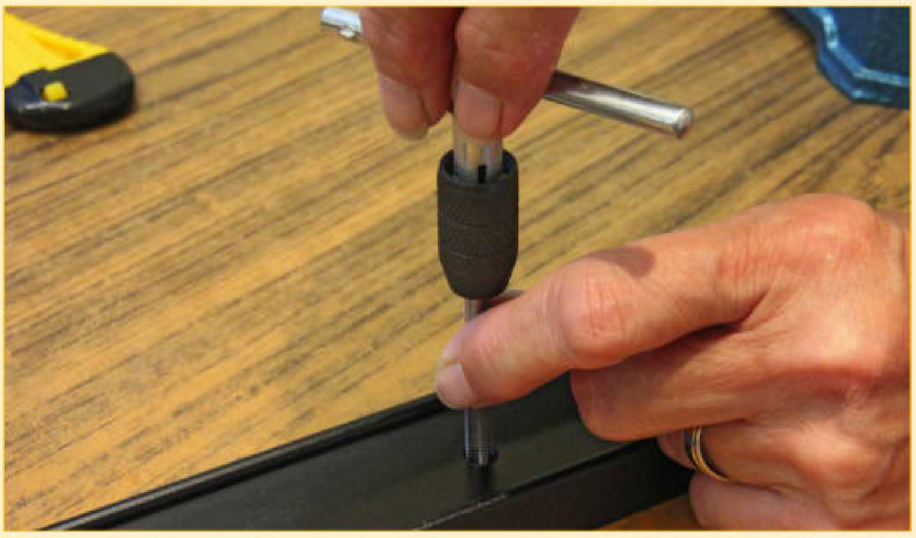


Step 1

Measure the gap between the bolt holes on the top of your tube rings. Attach masking tape to the new dovetail clamp and transfer this measurement to the clamp, centring it both longitudinally and laterally. Work out the thread size in the tube ring bolt holes.

Step 2

Drill and countersink two holes with a diameter of half a millimetre greater than the bolt size, in the marked positions on the dovetail clamp, ensuring that the holes are vertical. Use a vertical drill stand with a wood block placed under the clamp.

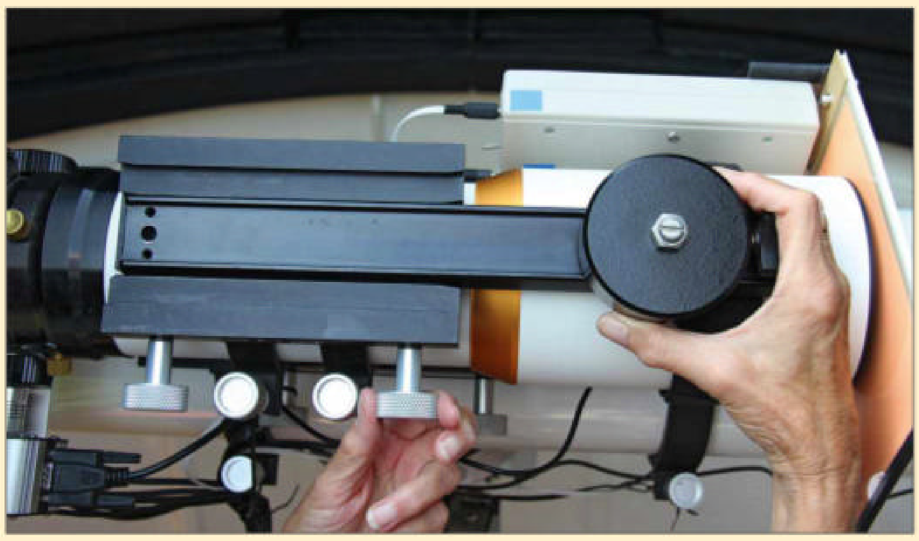


Step 3

Drill and tap a 6mm hole, 65mm from one end of the dovetail bar. Do a trial fit of the counterweight to the dovetail bar with a 6mm bolt, washer and Nyloc nut. Shorten and tidy up the thread on the bolt to ensure that it doesn't protrude through the dovetail bar.

Step 4

Set the mount in its 'Park' position with the counterweight(s) down and the scope pointing up, and slide the counterweight(s) down the counterweight bar away from the scope to make the weight side heavier. It's now safe to add weight to the scope side.



Step 5

Align the dovetail clamp with the top of the tube rings and do a trial of bolting the two together, making certain that the bolts are not long enough to pass right through the tube rings. Shorten and tidy up the bolt threads, then refit the bolts and tighten them.

Step 6

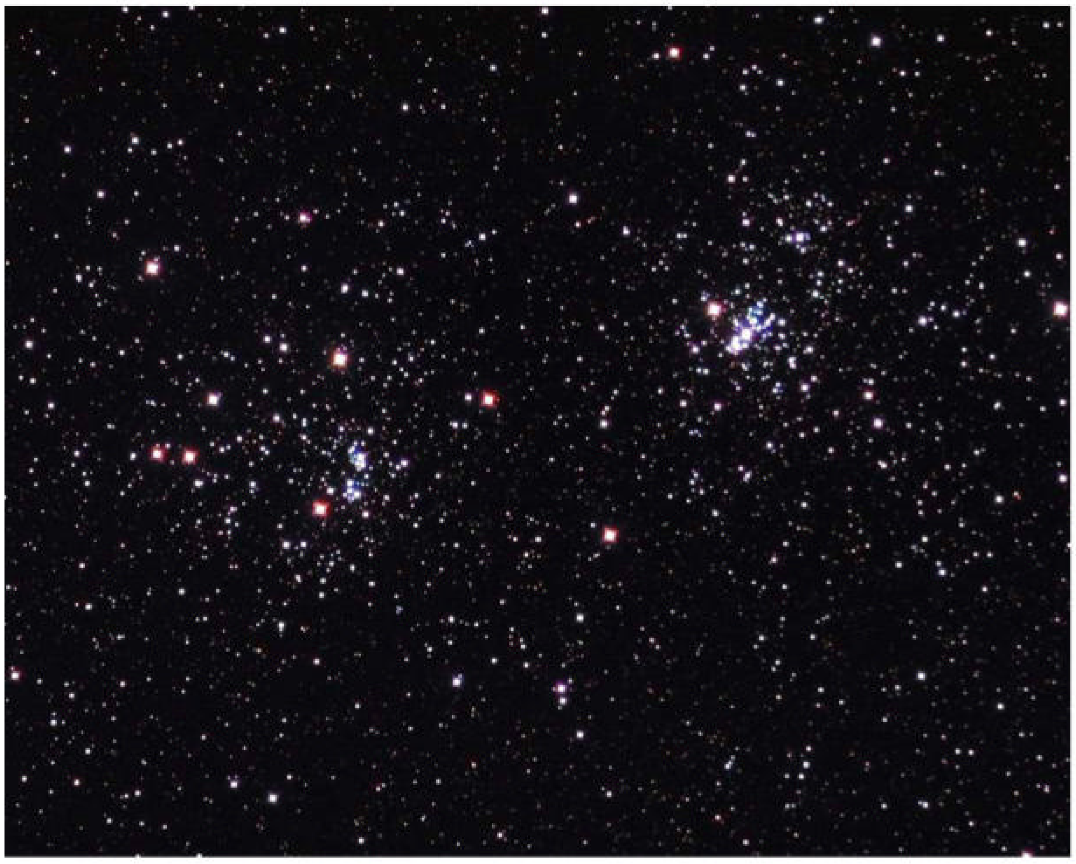
Slide the dovetail bar with the balance weight attached into the dovetail clamp, placing the weight on the side that needs to be heavier to attain declination (dec.) balance. Adjust the balance bar until the dec. axis is balanced, and then balance the RA axis.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Imaging the Double Cluster

Turn your camera towards Perseus to find the bejewelled handle of The Hero's sword



▲ **Blue-white supergiants feature in abundance in both of the clusters, while Chi (χ) Persei has the added bonus of a quintet of red supergiants**

Perseus rides high across the night sky at this time of year. The constellation represents the mythological Greek hero wielding his sword, the handle of which is marked by a rather special pair of deep-sky objects: two open clusters, which together are known as the Double Cluster.

The clusters are visible to the naked eye under dark skies and burst into life through binoculars or a small telescope. They're individually identified as h Persei and Chi (χ) Persei, or NGC 869 and NGC 884 respectively, and have a number of similarities. They shine with an integrated magnitude of +4.0, are similarly aged at 12.8 million years and are of similar distance: a 2010 study put the clusters at around 7,600 lightyears, although more recent research suggests the clusters lie about 8,100 lightyears from Earth.

Both also contain many massive stars. Within 10 arcminutes of their centres, they contain around 5,000 stars. An extensive outer star halo bumps the figure up to at least 13,000 and possibly as high as 20,000. Visually and photographically the number of stars seen is far lower than these figures suggest, but both remain very rich targets for astrophotography.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Easy to find, easy to see

The Double Cluster is easy to find. First identify the W-shaped constellation of Cassiopeia, which passes virtually overhead close to midnight BST during October. Extending the line from Gamma (γ) Cassiopeiae through Delta (δ) Cassiopeiae for twice the distance again will bring you to the Double Cluster.

A benefit of choosing stars as a target, as opposed to a diffuse, extended object such as a nebula, is that they have a resilience against light pollution. Light pollution may affect the colour of the surrounding sky, but stars are able to punch through.

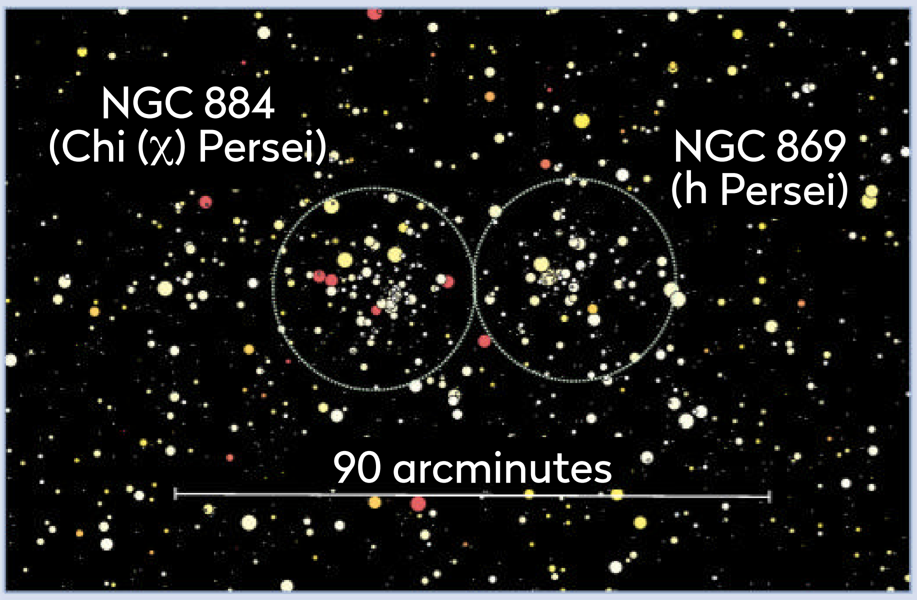
Photographically, h Persei and Chi Persei make excellent targets for DSLR cameras. A field width of 2° gives good coverage and this is easily achieved using a focal length of 1,000mm with a full-frame camera, or 600mm for an APS-C format sensor. The clusters sit against a portion of sky through which the Milky Way passes. As a consequence, a wider field also works very well and helps to put the pair nicely in context with their surroundings.

Both clusters contain a good number of blue-white supergiant stars. The eastern cluster, Chi Persei, contains five distinctive red supergiant stars that give excellent colour contrast with the other members. When photographing both clusters close up, it's worth adjusting your camera settings to really bring out these rich colours. Follow the steps opposite and see whether you can bag yourself a stunning photograph of this beautiful deep-sky duo.

Recommended equipment: a DSLR camera or equivalent, telescope or lens (see Step 1), polar-aligned tracking mount

Send your images to:
gallery@skyatnightmagazine.com

Step by step



STEP 1

Choose a lens appropriate to the view of the Double Cluster you want to portray. A 35mm format sensor camera coupled to a telescope with a 1,000mm focal length will cover an area 2° by 1.3° giving you a good close-up on the pair. If using a smaller APS-C sensor, a 600mm focal length achieves a similar field of view.

STEP 2

A wider view of the Double Cluster field will be less demanding on tracking accuracy and potentially show the area of Milky Way where they sit. A 35mm lens with an APS-C sensor or 60mm lens with a 35mm sensor will give enough of a field of view to include the whole of Cassiopeia as well as the Double Cluster.

STEP 3

A tracking mount will give the best results. A polar-aligned tracker can be used for cameras with lenses attached. If you're attaching your camera to a telescope, an equatorial mount will help carry the extra weight. If you have this setup already, you could piggy-back a camera with a lens fitted on the telescope.

STEP 4

A low ISO (200–400) will capture the Double Cluster's colours in the best way. Increasing the ISO gives an apparent increase in sensitivity but the higher you go, the more noise appears and the colours will start to wash out. Ensure the mount's polar alignment is as accurate as possible so you can take longer exposures.

STEP 5

Open the lens wide, perhaps closing by a stop or two if you see frame edge distortion. Set focus to manual, centre the Double Cluster and use 'Live View' focus assist to focus as accurately as possible. If you can't see stars, try setting the ISO higher. Using maximum zoom, adjust focus so the stars are crisp and sharp.

STEP 6

Set your exposure time for 30 seconds and take several shots. If you have a shutter-release cable, set the camera to 'Bulb' and take longer shots. Basic tracking mounts are limited to around 90 seconds for a close-up shot. The sweet spot is when you can use the longest exposure without signs of star trailing.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

APY Masterclass

How to enrich a nebula's colours

Use editing software to bring out hydrogen-alpha colours in Orion

Astronomy Photographer of the Year

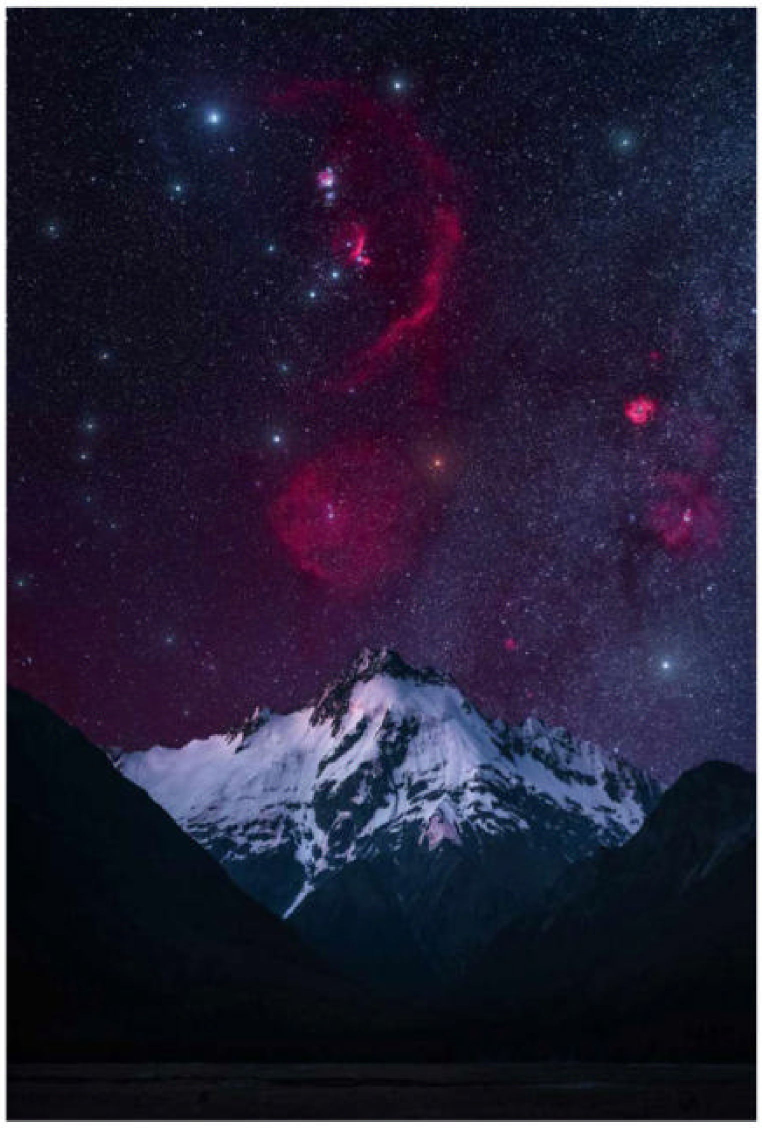
Advice from a shortlisted entrant in the 'Skyscapes' category

My 'Questions' image was shortlisted in the 'Skyscapes' category at the Astronomy Photography of the Year competition in 2020. I created it after deciding to take an image linking our planet to the sky, but without featuring the usual Milky Way core. I started by shooting a mountain panorama during the Blue Hour – when the last remaining sunlight casts a blue glow into the dusk – to get maximum detail, and then set up my gear and waited for darkness and the Orion Molecular Cloud Complex.

I used a hydrogen-alpha modified Canon EOS 6D camera with a 40mm Sigma Art lens at f/2, mounted on a Star Adventurer mount and took 38 frames, using exposures of 90 seconds at ISO 800.

I processed the image using a Luminance, Red, Green and Blue (LRGB) editing technique in Lightroom and Photoshop to bring out the hydrogen-alpha colours from the emission nebula. My friend and fellow astrophotographer Ian Norman showed me the technique and I'm going to explain how it works here. It involves stacking multiple shots to reduce noise (unwanted artefacts), creating a high-contrast 'Luminance' layer and then overlaying it with a 'Colour' layer to produce an image that reveals the data hidden in the RAW image files.

To begin the process select the RAW images (like I did of Orion) and import them into Lightroom. Next, click the 'Develop' module in the top menu and scroll down from the displayed 'Basic' panel (on the righthand side) to find the 'Noise Reduction' panel and set all the fields to 0. Scroll back up to the 'Basic' panel and set a neutral white balance by increasing 'Vibrance' and 'Saturation' values in the 'Presence' section to +100. Then, in the 'WB' (white balance) section of the 'Basic' panel, find an even balance between the colour sliders (Screenshot 1), before resetting 'Vibrance' and 'Saturation' to 0.



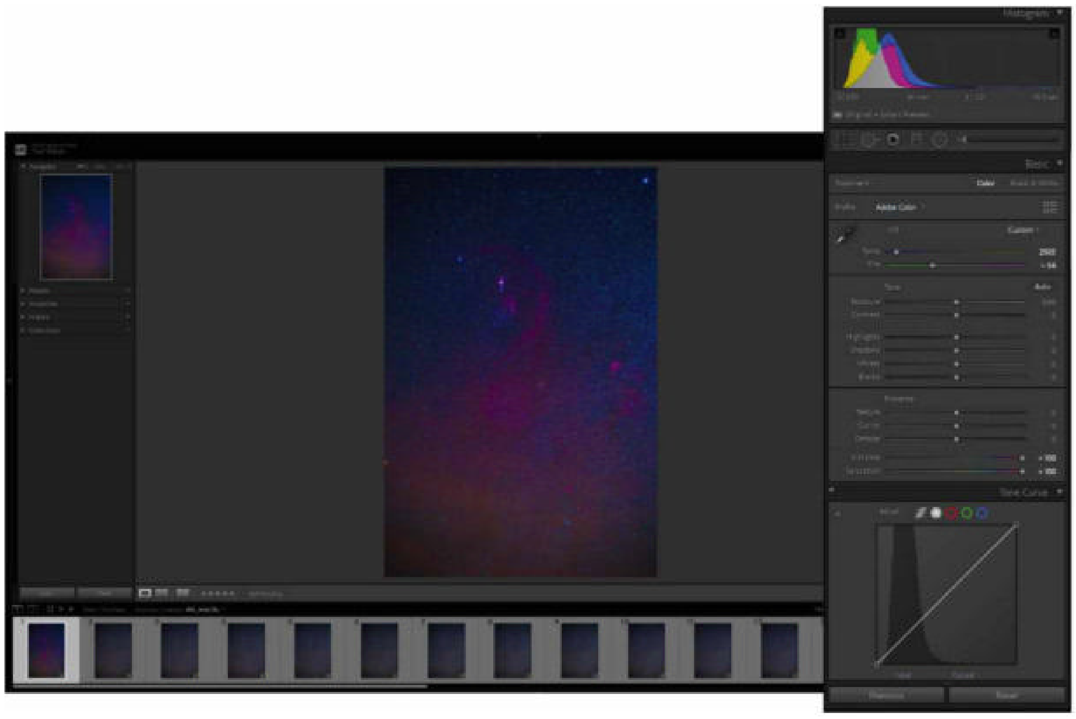
▲ **Paul's 'Questions' image combines a stunning mountain foreground in Canterbury Hill Country, New Zealand, with the rich, colourful detail of Orion**

ALL PICTURES: PAUL WILSON

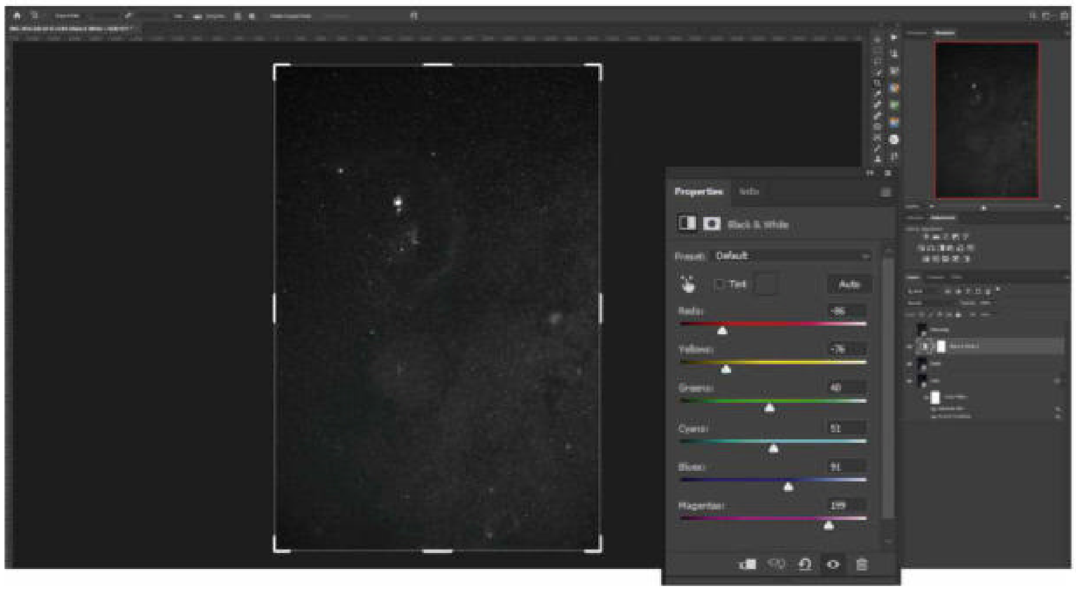
Create a panorama

Next, press 'Ctrl+A' to select all the images and click 'Sync' at the bottom of the 'Develop' module, which brings up the 'Synchronize Settings' box. Here click 'Check All' on the bottom left and then click 'Synchronize' on the bottom right. Now use the mouse to right-click on the selected images and select 'Edit in › Merge to panorama in Photoshop'. This launches Photoshop and loads the panorama window. In the 'Photomerge' option box untick 'Blend Images Together' and click 'OK'. Next, select all the images that Photoshop has opened in 'Layers', by right-clicking the mouse and selecting 'Convert to Smart Object'. In the top bar open the 'Layer' drop-down menu and click 'Smart Objects › Stack Mode › Median'. Right-click the image and select 'Flatten Image' to reduce noise.

Now that we have a 'Colour' layer we can create a high-contrast 'Luminance' layer. Use the mouse to right-click the 'Colour' layer and select 'Convert to Smart Object'. Next, press 'CTRL+J' a couple of times



▲ **Screenshot 1: In the 'White Balance' section of the 'Basic Panel', you can find an even balance between the colour sliders**



▲ **Screenshot 2: Adjust the colour sliders in the 'Black & White Properties' box to bring out contrast; an increase in 'Magenta' will enhance hydrogen-alpha**

▲ **Screenshot 3: Make adjustments to 'Curves' levels in the 'Nebulosity' layer**

to replicate the layer, making three. Rename the two new layers as 'Nebulosity' and 'Detail' and then hide them by clicking the eye icon to the left of the 'Layers' tab.

The next step is to remove the stars in the 'Colour' layer. Select it and then go to the top bar and open the 'Filter' drop-down menu and click 'Noise › Dust & Scratches'. In the 'Dust & Scratches' box set the 'Radius' to 8 (Pixels) and the 'Threshold' to 15 (Levels), as increasing the 'Threshold' will bring back detail. Doing this will eliminate all but the brightest stars. Smooth this layer by opening the 'Filter' drop-down menu again, and click 'Blur' › 'Gaussian Blur' and set the 'Radius' to 3 (Pixels) in the 'Gaussian Blur' box.

3 QUICK TIPS

1. The number values for this image may not fit your data, so alter them as necessary.

2. The key aim of LRGB processing is to enhance the hydrogen-alpha nebulosity in the image.

3 Be careful, as increasing the 'Black & White' luminosity too much may lead to data being lost.

We now need to adjust the 'Detail' layer. Select and unhide this layer by clicking on the eye icon in the 'Layers' tab, then find the 'Black & White' icon in the 'Adjustments' panel above the 'Layers' tab and click it. Adjust each of the colour sliders in the 'Black & White Properties' box (see Screenshot 2) to bring out contrast – for example, increasing 'Magenta' will reveal the hydrogen-alpha in your image. Next, click the 'Curves' icon in the 'Adjustments' panel and add contrast to your image with this tool. Under the 'Layers' tab, select 'Curves', 'Black & White' and 'Detail' and right-click the mouse on 'Smart Object'. Rename the adjusted layer as 'Detail'.

For the 'Nebulosity' layer, repeat the steps from the 'Colour' and 'Detail' layer (see Screenshot 3). Under 'Layers', select 'Curves', 'Black & White' and 'Nebulosity' and right-click on 'Smart Object'. Rename the layer as 'Nebulosity'.

Next, we combine the 'Detail' and 'Nebulosity' layers with an inverted layer mask. To do this, hide the 'Nebulosity' layer and select the 'Detail' layer. Press 'CTRL+A' to select the main image preview shown on the screen. Use 'CTRL+C' to copy it, and then re-enable the 'Nebulosity' layer and add a layer mask by clicking 'Add vector mask' at the bottom of the 'Layers' tab. Paste the copied contents into the new mask on our 'Nebulosity' layer. Hold 'ALT' and click on the mask, before pressing 'CTRL+V' to paste and then 'CTRL+I' to invert the contents. Group the 'Nebulosity' and 'Detail' layers by selecting both, then press 'CTRL+G' and set the group blend mode to 'Luminosity' – this creates our 'Luminance' layer. Now select the 'Colour' layer and click the 'Vibrance' and 'Hue/Saturation' icons in the 'Adjustments' panel to make increases. We can now combine our layers by right-clicking and selecting 'Flatten Image'.

Finally, the mountain can be added by opening the image of it and using Photoshop's 'Magic Wand Tool' to select the foreground. We apply a layer mask where the sky is black and the ground is white to create our final image (see the main 'Questions' image, opposite).

Paul Wilson is an astrophotographer based in Christchurch, New Zealand. He was shortlisted in the APY 2020 'Skyscapes' category with 'Questions'

Your best photos submitted to the magazine this month

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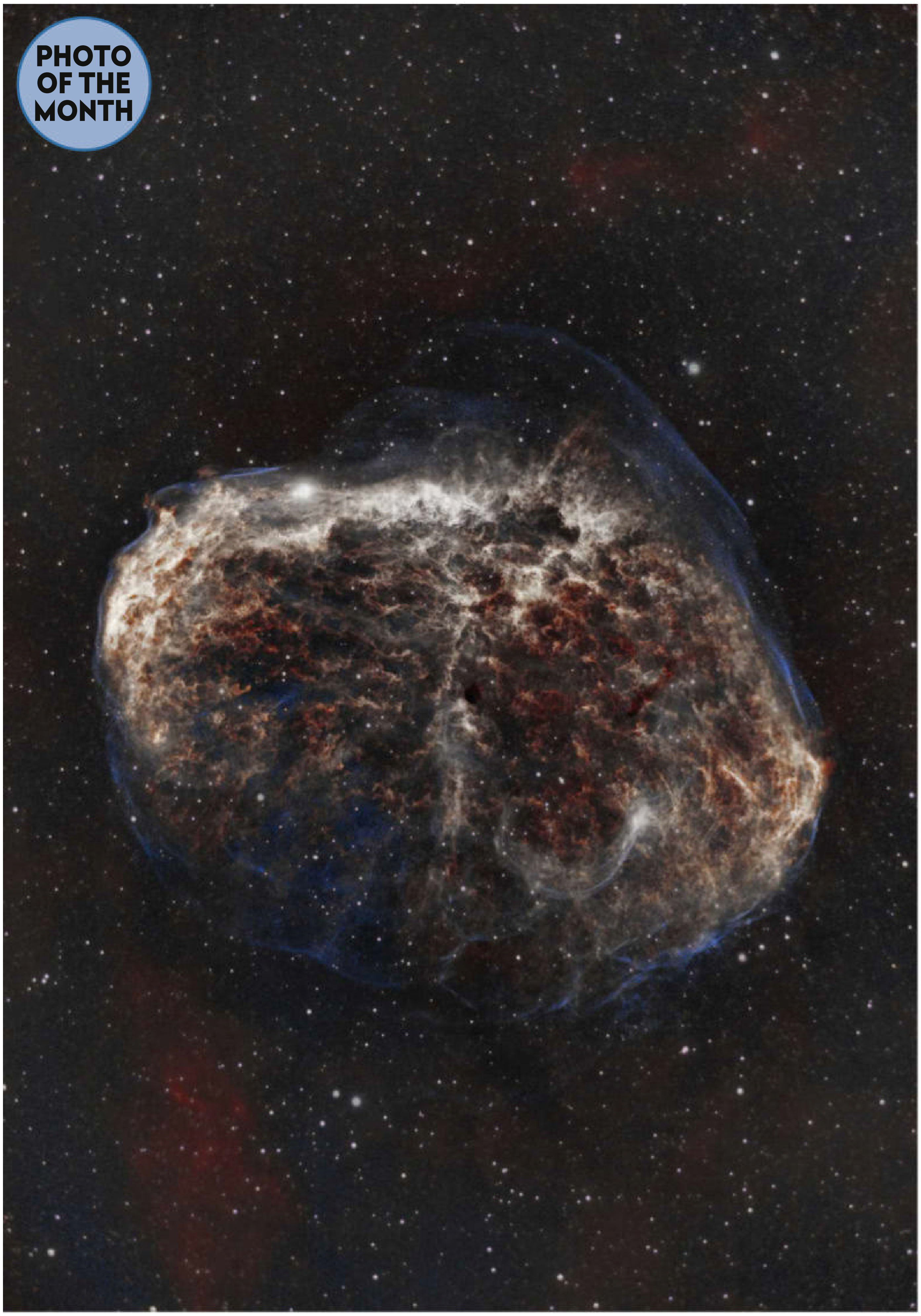


◁ The Crescent Nebula

Andy Weller, Sandy, Bedfordshire, 16–17 July 2021

Andy says: "I've only been doing astrophotography for a year, starting during lockdown – as many people did. This target always appealed to me because of its jarring resemblance to a human brain just hovering in space. Its interesting layers of gasses give it an almost ghostly look and feel."

Equipment: ZWO ASI294MC Pro camera, Celestron C11 XLT Schmidt-Cassegrain, Sky-Watcher EQ6-R Pro mount
Exposure: 73x 4', gain 120
Software: PixInsight, Affinity Photo, Topaz DeNoise

Andy's top tips: "The Crescent Nebula is full of fine detail, so try to retain as much as possible while not allowing noise (unwanted artefacts) to dominate. I spent a good third of my time on noise reduction. Because of light pollution from LED streetlights, I used a 7nm dual-narrowband filter to capture the Ha (hydrogen-alpha) and OIII (oxygen) wavelengths, and I constructed shields around my scope to create shade.

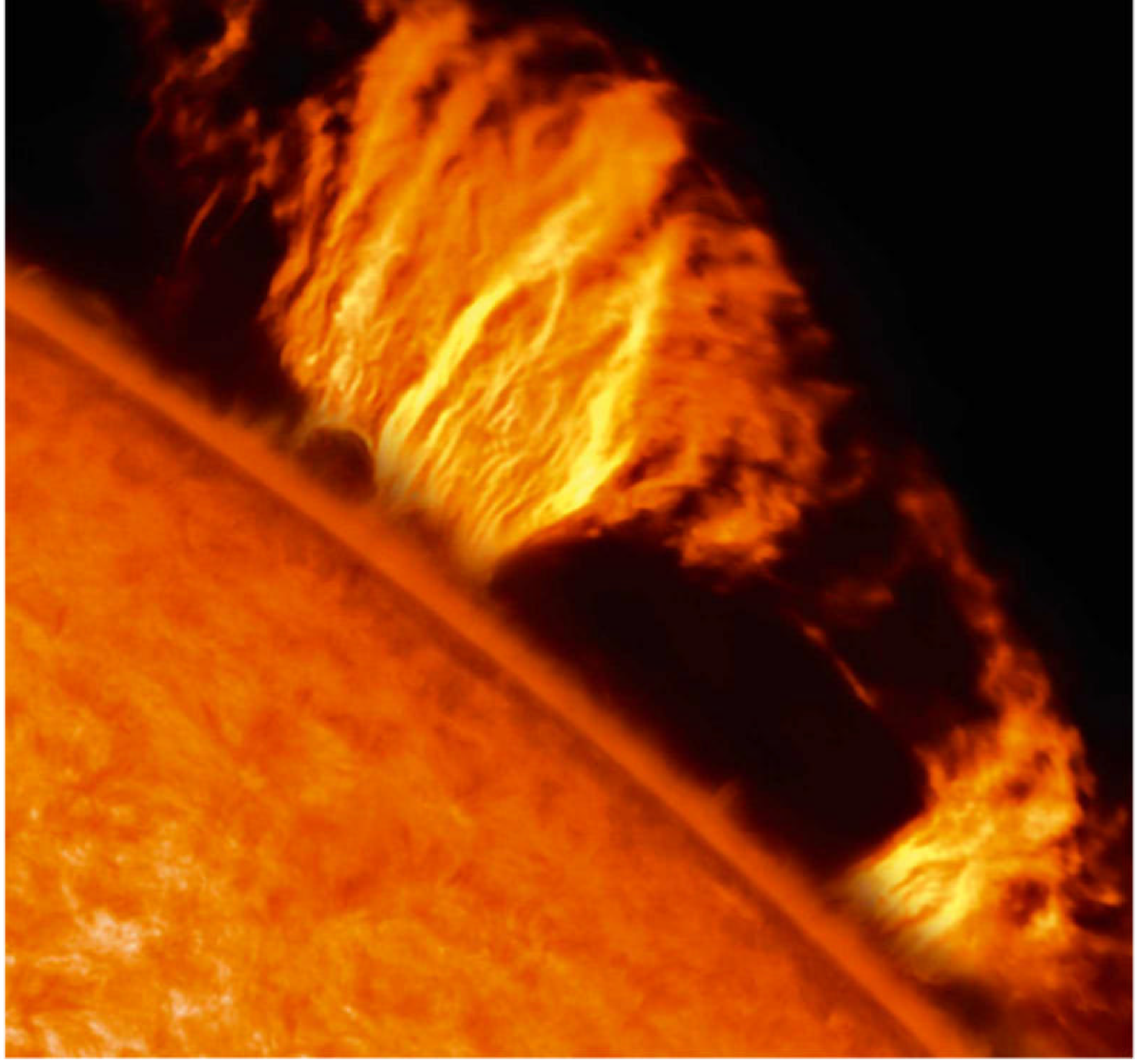
I experimented with colours by splitting out and recombining the Red, Green and Blue channels until I struck upon the look and feel I wanted. Don't be afraid to experiment; in the worst case scenario you just start again."

Solar prominence ▷

Daniel Zoliro, Oklahoma, USA, 11 June 2021

Daniel says: "I've enjoyed the challenges of solar imaging."

Equipment: ZWO ASI1600MM Pro camera, Astro-Tech AT115EDT apo refractor, DayStar Quark Chromosphere, Sky-Watcher EQ6-R Pro mount **Exposure:** 1,400 frames at 46fps **Software:** AutoStakkert!, Photoshop, PixInsight

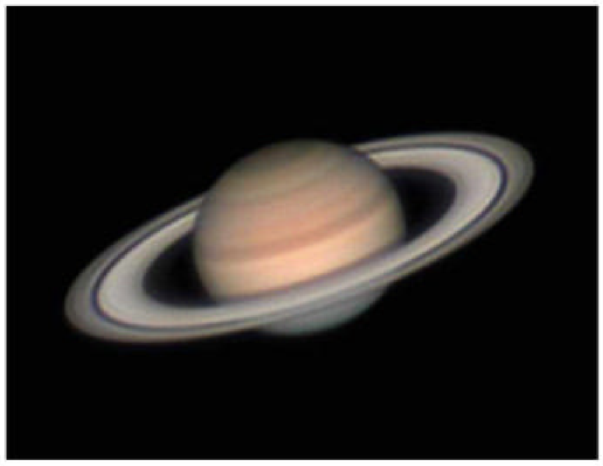


▽ The Milky Way over Maine

Prashant Naik, Maine, USA, 10 June 2021

Prashant says: "This panoramic arch is made up of 20 vertical frames stacked and blended together in Lightroom and Photoshop."

Equipment: Nikon D810 DSLR, Nikkor 14–24mm lens, Induro CLT204 tripod **Exposure:** ISO 8000, f/2.8, 15" **Software:** Lightroom, Photoshop



◁ Saturn

Dmitry Ardashev, Zaprudnya, Russia, 26 July 2021

Dmitry says: "I was pleasantly surprised by this photo's sharpness. At the time, Saturn was 15° above the horizon."

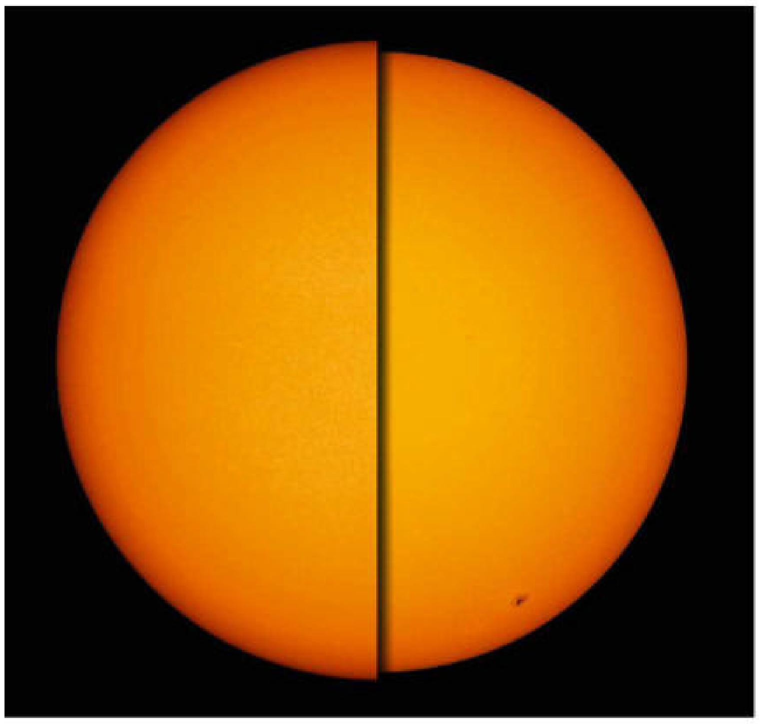
Equipment: ZWO ASI462MC camera, TS-Optics UNC 10-inch Newtonian, Sky-Watcher EQ6-R mount **Exposure:** 40,000 video frames at 25.88ms, best 3,000 stacked **Software:** FireCapture, AutoStakkert!, AstroSurface, Photoshop

The Heart and Soul Nebulae ▷

Simon Todd, Haywards Heath, November 2020–February 2021

Simon says: "This two-panel mosaic is the first I've tried with this camera. I stacked each panel and then used the 'Mosaic Tool' in Astro Pixel Processor to merge them into a mosaic just short of 100 megapixels."

Equipment: ZWO ASI6200MC camera, SharpStar 15028HNT astrograph, Sky-Watcher EQ8 Pro mount **Exposure:** 101x 300" per panel **Software:** Sequence Generator Pro, APP (Astro Pixel Processor), PixInsight



△ The Sun at perihelion and aphelion

Andrei Dumitriu, Bucharest, Romania, 2 January and 5 July 2021

Andrei says: "The perihelion and aphelion dates printed in your January issue (in 'The Sky Guide' on page 44) inspired me to capture the 3 per cent size difference between the 'two' Suns. January's perihelion Sun is on the left and July's aphelion Sun is on the right."

Equipment: ZWO ASI178MC camera, Orion ED80 apo refractor, Sky-Watcher Star Discovery mount **Exposure:** 0.9ms, gain 0 (perihelion); 0.3ms, gain 97 (aphelion) **Software:** AutoStakkert!, RegiStax, Photoshop

△ Early Perseid passing close to Jupiter

Steve Brown, Stokesley, North Yorkshire, 3 August 2021

Steve says: "Having had no luck catching early Perseid meteors, I repositioned my camera to take some shots of Jupiter. I'd just hit the shutter release on a test shot when the meteor appeared, resulting in this very lucky capture."

Equipment: Canon 250D DSLR camera, Canon 50mm lens, Camlink TP-2800 tripod **Exposure:** ISO 1600 f/2.0, 5" **Software:** Photoshop

Mineral Moon ▷

Neil Corke, Moraira, Spain, 22 July 2021

Neil says: "This was my first attempt at astrophotography and I'm really pleased with the result."

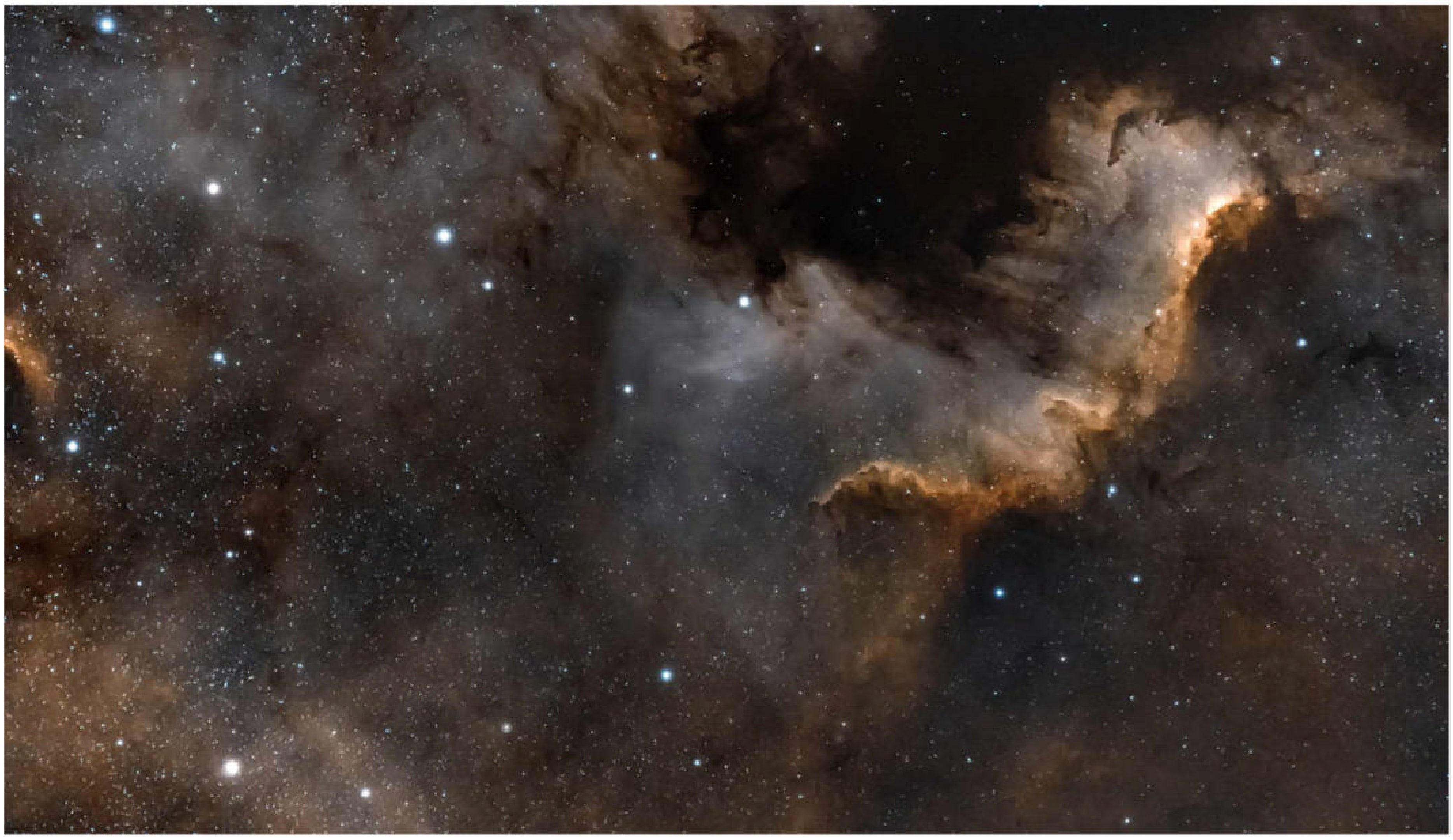
Equipment: ZWO ASI2600MM camera, Williams Optics FLT 132 apo refractor, Paramount MX mount **Exposure:** 300" video **Software:** FireCapture, AutoStakkert!, PixInsight

▽ The North America Nebula

Rachael and Jonathan Wood, Doncaster, 15 June 2021

Rachael says: "I'm a fan of the Hubble Palette, so I used a one-shot camera and an L-eNhance filter to split Ha and OIII wavelengths into individual channels; then I coloured and combined them with a green made by blending the Ha and OIII layers."

Equipment: ZWO ASI294MC Pro camera, Sky-Watcher Evostar ED80, Sky-Watcher HEQ5 Pro mount **Exposure:** 2h 10' total **Software:** Astro Pixel Processor, Photoshop



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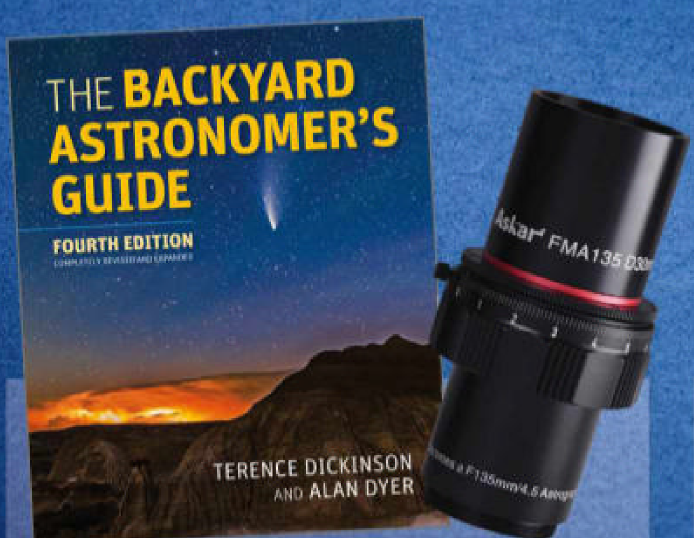
86
Promising a full-frame sensor and speedy video capture, we put the Sony A9 mirrorless camera through its paces



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PLUS: Books on the northern lights and a new edition of an astronomy classic, plus a roundup of must-have gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★ Very good ★★★ Good ★★ Average ★ Poor/avoid

Sony A9 mirrorless camera body

A full-frame camera that's enjoyable to use and packed with impressive features

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £3,399
- **Sensor** 35mm full frame (35.6mm x 23.8mm), Exmor RS CMOS sensor
- **Megapixels** 24.2MP
- **ISO range** 100–51,200, expandable to 204,800
- **Live View** Magnify image 4.7x, 9.4x for manual focusing
- **Lens mount** Sony E-mount
- **Size** 126.9mm x 95.6mm x 63mm
- **Weight** 676g
- **Supplier** Sony
- **Tel** 0207 365 2810
- **www.sony.co.uk**

Good things come in small packages, and when we opened the Sony Alpha 9 (A9) box we were surprised at how compact the enclosed camera body was; being about two-thirds the size of other full-frame cameras on the market. Indeed, this is a camera we know we won't have any issues with when we are balancing it with a long lens or small telescope. The body fits nicely in the hand, while the control wheels – for changing ISO, exposure time and f/numbers – are very accessible and easy to locate by touch in the dark. While such a compact camera is always desirable for astrophotography, we did however note that the gap between the grip and lens mount was quite small, which may pose an issue for larger hands.

We liked the Sony A9's four customisable 'C' buttons from the outset; these give the user a lot of flexibility when it comes to adapting the camera configuration. The LCD screen is moveable, but not fully articulated; while we could pull out and tilt the screen at an angle, we couldn't rotate it.

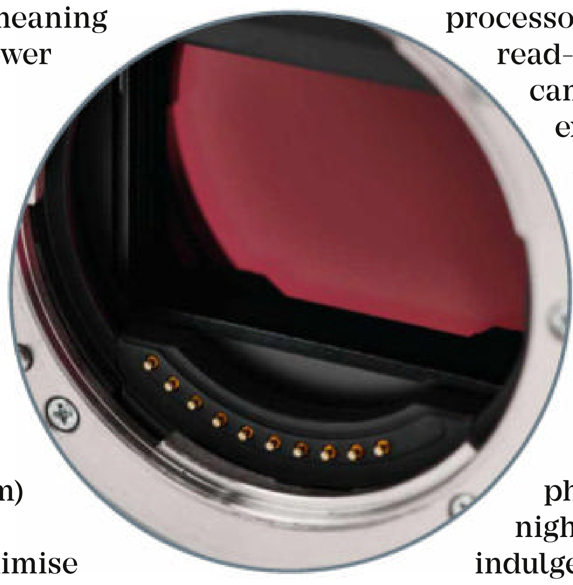
As clear summer skies beckoned, we headed out to put the Sony A9's 24MP sensor through its paces with some Milky Way imaging. The first thing we noticed while setting up was that the Sony A9 has a touchscreen – up to a point. We found that we could tap to set the focus point of our image, but we could not change the settings or take images via the LCD monitor. This isn't an issue if using an intervalometer (interval timer), or if the shutter button is sensitive. Luckily, the A9 is very responsive, and even when we weren't using a remote shutter release it didn't pose an issue. Indeed, in lighter summer night skies, high ISO test images appeared clean.

Deep-sky impact

The Sony A9 really excelled when we used it to locate and focus on deep-sky objects. The 'Live View' was exceptional and sped up our setup time considerably. While stars showed up easily on screen, we found the camera's focusing was impressive. By switching on 'MF Assist' (manual focus assist) in settings, it allowed the 'Live View' to automatically zoom in on our set focus point whenever we moved the focus ring on our lenses. (This avoids the hassle of finding a 'Magnify' button to press, which risks nudging the setup). While ▸

Full-frame sensor flexibility

Full-frame cameras generally offer greater ISO performance and sensitivity, meaning cleaner, noise-free images (with lower unwanted artefacts) in low light conditions. Even when we were shooting at ISO 3200 in light, summer night skies we yielded impressively clean images from the A9. The wider field of view that full-frame cameras provide makes them excellent nightscape and Milky Way devices. It also means we can use lenses at their true focal length.



The full frame (35.6mm x 23.8mm) Exmor RS 24MP CMOS sensor is a standout feature. Designed to maximise the frame rate, the sensor is stacked onto a processor that optimises the sensor's read-out time, which means the camera won't lag between long exposure shots. What's more, the A9's 'Live View' setting is among the best we've seen and it sped up our deep-sky setup process in challenging conditions. The speedy processor also allows the A9 to show video at up to 100fps and makes the camera faster and more flexible for the user.

The A9 will excel in daytime photography and hold its own for nightscapes and for those wishing to indulge in a little deep-sky imaging too.

SCALE

Customisable buttons

The A9 body has four 'C' buttons that can be customised and programmed to the preferences of the user. This helps to make the camera even easier to use in low light; simply programme these buttons to perform the functions you want and the camera is tuned to individual users.

4K video

The A9's impressive 100fps maximum shooting speed comes in handy for lunar and planetary imaging, as it allows you to cut through atmospheric turbulence more effectively. In order to shoot in 4K, a memory card with a V30 rating must be used, as this has the write-speed capability needed.

Mirrorless design

Due to having no internal mirror the A9 is light to handle – and quiet. In fact, the 'shutter sound' that the A9 defaults to can be turned off, which allows you to shoot in complete silence at night. The A9 is as close to vibration-free as possible, which is a key attribute for an astro camera.

Adjustable LCD monitor

A moveable screen is always a bonus for DSLR astrophotography, especially when shooting deep-sky images. The LCD screen can easily be pulled out from the body and angled for more comfortable viewing. This helps if lining up a deep-sky object, focusing in 'Live View' or reviewing images.

FIRST LIGHT

KIT TO ADD
1. Sony 70–350mm G lens
2. Sony FE 16–35mm GM lens
3. Sony E-mount T-ring

▸ we didn't think the Sony A9 was particularly sensitive to Hydrogen-alpha (Ha) wavelengths, this may have been due to the seasonably light skies and a rising full Moon.

The Sony A9's 'Interval Shooting' function is a game changer; it allows astrophotography newcomers the chance to try multiple long exposure deep-sky shots without the need for an intervalometer. While the maximum exposure time is only 30 seconds in this mode, this is ample enough to do justice to many deep-sky objects and is certainly enough for Milky Way wide-field imaging.

For those wishing to attach the Sony A9 to a telescope, it's worth noting that a Sony E-mount T-ring is required, which is different to the standard A-mount T-ring many Sony cameras use. An A- to E-mount adaptor is also available to purchase, which may come in handy for astrophotographers who are moving from cameras with crop sensors into Sony's full-frame line. While crop sensor lenses can be used – as long as the A9 is in crop sensor mode – there are full-frame variants available up to 600mm.

Shooting the Moon

With the full Moon cutting our deep-sky object time short, we tested out the five-axis image-stabilisation by taking some handheld shots. We were impressed, as we were able to keep the Moon central over several images and recover good details on the lunar surface later in post-processing. The battery lasted across three nights of imaging before it needed charging, totalling about 4.5 hours. This is about the fastest, quietest 'mirrorless DSLR' we've tried – every long exposure, high ISO frame we took was read and processed with no 'blackout', meaning we were able to minimise the interval between shots.

Overall, the Sony A9 is an easy to navigate, enjoyable compact, full-frame camera with plenty of pleasing hidden extras. It also transitions seamlessly from daytime to night-time photography.

VERDICT

Build & design	★★★★☆
Connectivity	★★★★½
Ease of use	★★★★☆
Features	★★★★½
Imaging quality	★★★★☆
OVERALL	★★★★☆

▲ A handheld picture of the Moon, taken with the Sony A9 mirrorless camera and a Sony 70–350mm G lens set at 350mm – with a 1/250 exposure at f/6.3 and an ISO setting of 1600

▲ Part of a Milky Way panorama taken with the Sony A9, using a Sony FE 16-35mm GM lens at 20mm, using 12 images stitched in Microsoft ICE. Each panorama frame was taken with 15" exposures at ISO 3200

In-built interval shooting

This is an excellent addition for newcomers to astrophotography who want to have a go without investing in additional kit such as an intervalometer. Located in the main menu, simply select how many frames to take and the exposure time (maximum 30 seconds) and the Sony A9 will fire off multiple images to stack.

Explore Scientific BT-100 SF Giant Binocular

A super-sized set of binoculars for views with greater clarity and contrast

WORDS: STEVE TONKIN

VITAL STATS

- **Price** £1,445.20
- **Optics** Fully multi-coated (Enhanced Multilayer Deposition)
- **Aperture** 100mm
- **Focal length** 550mm, f/5.5
- **Eyepieces & magnification** 20mm, 28x
- **Angular field of view** 2.3°
- **Focusing** Individual focus
- **Eye relief** 15mm
- **Interpupillary distance** 54–76mm
- **Weight** 6.8kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

Nothing quite matches the pleasure of scanning a clear, dark sky with big binoculars, so Explore Scientific's new 100 SF Giant Binocular – part of its Binocular Telescope (BT) series – looks like an attractive option, in theory. But how does it fare in practice?

The binoculars come protected in a foam-lined box, which includes the 20mm, 62°, Argon-purged eyepieces. After you've secured them into their focusers, you can focus the eyepieces individually with self-centring compression rings. They have fold-down eyecups and just enough eye relief to allow you to see the entire field of view if you wear spectacles. You adjust the interpupillary distance (IPD) – the distance between the pupils of your eyes – with levers on the eyepiece holders. These move smoothly and are sufficiently stiff to make it unlikely that you'll alter the IPD when you're focusing or changing eyepieces. The helical focusers rotate smoothly, making it easy to get a pin-sharp view.

For this review the binoculars were mounted on a Universal Astronomics T-Mount (with a load capacity of 13.5kg), which was an ideal platform. There are no trunnions (cylindrical protrusions used as a pivot point) on the BT-100 binoculars for a yoke-type mount. If that's your preferred option you'll need a mount with a mounting plate suitable for larger binoculars like those in the BT series, such as Explore Scientific's U-Mount with tripod. The BT-100's base can also be attached to camera or video tripods, but you will need a very substantial tripod head to do so.

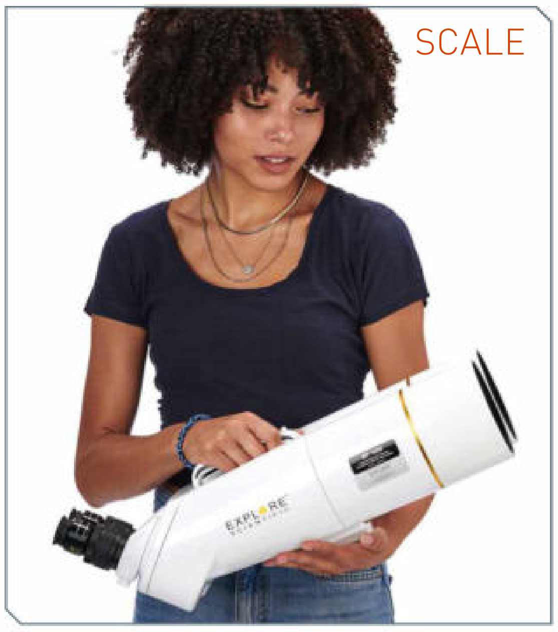
Two become one

At first light, the binoculars were producing double images. Fortunately, the BT-100 is designed to be collimated by the user. By using a lens spanner to rotate the eccentric rings around the objective lenses and, after a bit of refinement on the star Polaris, we found that the images had merged acceptably. You can't adjust the eccentrics while you're at the ▸

Reflection reducers

Look into the objective lenses of the BT-100 binoculars and two things immediately become apparent. The first is how transparent they appear – a consequence of Explore Scientific's proprietary Enhanced Multilayer Deposition (EMD) anti-reflective coatings. These use the optical phenomenon of destructive interference to reduce reflection. Light that is not reflected from a transparent surface must be transmitted through that surface, resulting in brighter images.

This transparency allows you to notice the second thing: two rings on the inside of the objective tubes. These are light baffles and their job is to intercept any light reflected off the inside wall of the tubes so that it can't reach the prisms and eyepieces where it could cause ghost images or image degradation. They are positioned so that they don't intercept light directly from the objective lenses, so the image-forming light is all transmitted. The result is a bright, high-contrast image in the eyepiece, enabling you to make out subtle detail and detect fainter objects – a desirable trait in any optical device.



Sight

Binoculars with angled eyepieces need some form of finder, so there's a 'vee and post' sight on the handle. It's difficult to see in the dark, but you can illuminate it with a faint red torch. If you prefer to add a finder, the handle is pre-drilled for a finder-mounting shoe.

Waterproof and nitrogen-filled

Humid air is ruinous to optical systems and the IPX6-rated waterproofing is easily enough to prevent dew. The nitrogen filling is another line of defence: in the unlikely event that humid air does get inside, the nitrogen will inhibit fungal growth and the oxidation of metal parts.

Mount options

The base has two ¼-inch Whitworth holes, spaced to match a Vixen/ Sky-Watcher dovetail bar, and one ⅜-inch Whitworth hole. These are standard photographic threads, so they fit a range of tripod quick-release plates. Using two holes eliminates the possibility that the binoculars will rotate on the plate.

FIRST LIGHT

Interchangeable angled eyepieces

Observing targets higher than 50° in straight-through binoculars can be very uncomfortable, especially if you're standing, but the BT-100's 45° eyepieces make viewing such objects much more comfortable. They're a standard 1.25-inch fit, so you can use different eyepiece pairs to get a variety of magnifications.

Dew shields and lens caps

The dew shields extend 90mm beyond the front of the objective lenses, giving adequate dew protection for a few hours. The lens caps screw into the objective tube, so not only are they secure, but they also lock the dew shields so that they can't be accidentally extended.

▸ eyepiece end though, so in-the-field collimation is really a two-person task.

Some false colour is inevitable in a 100mm, f/5.5 achromatic lenses, so we tested them on Vega (Alpha (α) Lyrae). Although it was difficult to detect 'on-axis' chromatic aberration – an effect usually seen as coloured rings around brighter objects – at the centre of the field of view, some false colour did become apparent 'off axis', further away from the centre of the field of view.

Jupiter and Saturn were shining brightly, low in the southern sky, during the test period and both showed the effects of atmospheric dispersion. It's possible to counteract this, to some extent, by finding the spot in the bottom half of the field of view where the atmosphere partially corrects chromatic aberration. At this 'sweet spot', Jupiter's equatorial belts became visible, and it was possible to discern dark space between Saturn's rings and the planetary disc. A number of faint points of light near Saturn were later revealed as the moons Titan, Tethys, Dione and Rhea after cross-referencing them in a planetarium app.

Reflections and contrasts

When Jupiter was a degree or so below the field of view, it was sometimes possible to see a horizontal flash of light that was probably a reflection of a prism edge. It appeared impossible to induce any spurious reflections from objects that were either within or immediately outside the field of view, however.

The next target was Albireo (Beta (β) Cygni), which displayed two sharp components with the gold and sapphire colour contrast; the rendition was good.

The 1.25-inch eyepieces on the BT-100 are threaded for filters. After inserting a UHC (ultra-high contrast) filter in one, the binoculars revealed the structure in the Dumbbell Nebula. And after panning over to the Ring Nebula, it was possible to 'blink' it, making field stars fade and re-emerge by swapping between the filtered and unfiltered eyepieces.

The strength of the BT-100 binoculars is viewing clusters and galaxies. M31 overflows the field of view and M81 and M82 fit easily within it. It was also a joy to identify open clusters in the northern Milky Way.

This is a well-implemented achromatic set of binoculars that will appeal to observers who want a capable, large-aperture instrument without the extra expense of a premium apochromatic design.

VERDICT

Build and design	★★★★½
Ease of use	★★★★★
Features	★★★★½
Field of View	★★★★½
Optics	★★★★☆
OVERALL	★★★★½

KIT TO ADD

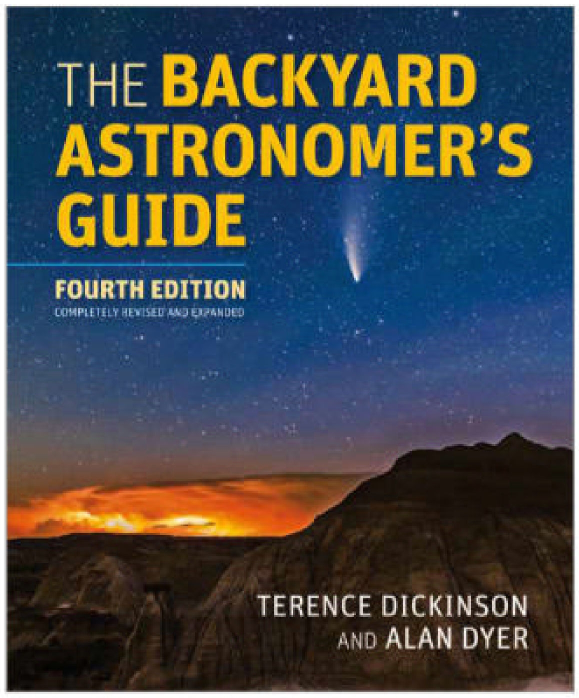
1. Explore Scientific U-Mount with tripod for giant binoculars

2. Fotomate VT-680-222R extra-heavy-duty professional two-way tripod

3. Explore Scientific 1.25-inch UHC nebula filter

New astronomy and space titles reviewed

BOOKS



The Backyard Astronomer's Guide

Terence Dickinson, Alan Dyer
Firefly Books
£35 ● HB

Get excited – the fourth edition of *The Backyard Astronomer's Guide* is here. First published in 1991, the latest edition boasts 48 additional pages and five new bang-up-to-date chapters. Beautifully put together by authors Terence Dickinson and Alan Dyer, the new edition firmly brings the book into the modern age of astronomy.

Spanning 416 pages and split into four parts, it covers how to get started, choosing and using a telescope, the telescopic Universe and capturing the cosmos. Within each part are chapters to wow and inspire and prove that you too can view the Milky Way, lunar eclipses, planets and constellations with just the naked eye. There are some truly stunning images packed in to take your breath away and motivate you to get outside. Perhaps the most vital chapters are the guides on what binoculars to buy; plus choosing, buying and then using a telescope – an absolute must for those considering purchasing their first piece of optical equipment.

The guides explain everything from aperture, power and optical design to mounts and filters, each illustrated with handy photographs ensuring the reader knows the difference between a Newtonian and Maksutov telescope or an altazimuth and Go-To mount.

Among the pages are sky tours, star charts, future astronomical events and a fantastic short Moon tour by astronomy communicator Ken Hewitt-White.

The authors really help manage a beginner's expectations, giving honest advice such as 'leave astrophotography to the last' – an important lesson that first-time astronomers often ignore.

This invaluable guide will appeal to anyone no matter their experience, the equipment they have (or not) or where they live. Dickinson and Dyer do just that with this book – emphasising that astronomy truly is a hobby for all, no matter the limitations. The authors write with years of experience and it is well worth the attention – it might be the best advice you pay for. The only downside to this book is that it's not printed in paperback and ring-bound to make it easier to use outside and take full advantage of these resources! ★★★★★

ROBERT LANE/ISTOCK/GETTY IMAGES

The latest edition helps beginners manage expectations and choose the right gear

***Katrin Raynor Evans** is an amateur astronomer, a fellow of the Royal Astronomical Society and the librarian for Cardiff Astronomical Society*

Interview with the author
Alan Dyer

What advice would you give beginners?

Take time to learn your way around the sky. People often want to buy a telescope right away. Don't. Instead of spending money, spend time with star charts to identify the brightest stars and constellations. Use binoculars to hunt down famous objects such as the Andromeda Galaxy.

What's in this new updated edition?

Almost every page and paragraph received updates, including wholesale rewrites and new images. We updated our equipment recommendations in chapters on buying binoculars, telescopes and accessories. Also new are three chapters with tours of selected regions of the Moon, and our picks for samplers of deep-sky targets for both binoculars and small scopes.

What's changed since the first edition?

The hobby has been revolutionised by digital technology. Even since the third edition in 2010, the gear and software we use has changed. Smart phones and tablets were just coming into their own; not to mention social media. The new edition reflects this.

What upcoming astronomical events should be in our observing calendar?

The highlight of the coming year is the run of semi-annual eclipses of the Moon. We have an almost-total eclipse on 19 November, followed by two deep total eclipses in 2022, first on 16 May, then on 8 November. The UK misses out on the latter. To make up for it, Britons can enjoy a partial eclipse of the Sun on 25 October 2022.

***Alan Dyer** is an astrophotographer, eclipse chaser and author of several best-selling astronomy books*

Fire and Ice: The volcanoes of the Solar System

Natalie Starkey
Bloomsbury
£16.99 ● HB

Fire and Ice: the Volcanoes of the Solar System is a masterful geology lesson disguised in the excitement of fire, ice and alien worlds.

When you think of a volcano, you are probably thinking of something you made at school: a tall cone-shaped structure with bubbling 'lava' cascading down the side. In this assumption you would be right, but also simultaneously completely wrong. *Fire and Ice* will introduce you to a whole range of volcanoes, from those forming under pressure at the bottom of the ocean, to the moving wonder of hot spots from the core of Earth forming island chains in the middle of nowhere, to those that are pouring out blue flames – and those are just on our planet.

Beyond Earth, you will learn about the largest volcano in the Solar System (Olympus Mons), the cryovolcanoes made of solid ice spraying jets of salty water tens of kilometres into space, and how a world can be stretched so much it has tides of molten rock that are five times as high as the ocean tides on Earth.

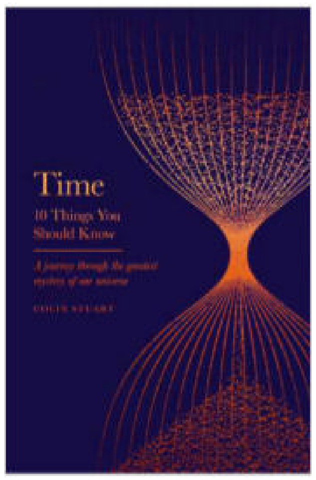
This is highly recommended for anyone who has ever been fascinated by the glow of a volcano, or wondered if there is life 'out there'. The author combines events at the frontier of Solar System exploration with our knowledge of the role of Earth's volcanic activity to take a look beyond and answer: what really is a volcano? ★★★★★

***Dr Hannah Wakeford** is an astrophysicist at the University of Bristol who studies exoplanets using space telescopes*

Time: 10 Things You Should Know

Colin Stuart
Seven Dials
£9.99 ● HB

SHORT READ, BIG IDEAS



For such a familiar concept, time is actually a rather complex topic. There are subtleties, such as how exactly we measure it, but also debates as to what it even *is* in a physical sense. But it turns out that discovering more about the nature of time doesn't have to take a lot of it. In *Time: 10 Things You Should Know*, you can cover a lot of ground in just 100 pages.

The book is made up of 10 essays, each 10 pages, covering a different aspect of time. To begin with, they're fairly straightforward, starting with the definition of how we measure time – you've heard of leap years, but why on Earth do we need leap seconds? It moves on to other ways we mark and measure time, both here on Earth and with time-travelling telescopes.

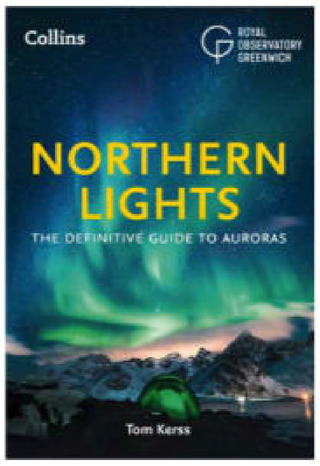
The middle chapters cover the very nature of time and how we experience it, and it's not long before you find yourself discussing the implications of general relativity. The later chapters of the book investigate how time can be manipulated and what that might mean. Whether that means trying to slow time (or even stop it!) or travel through it (being careful not to kill your grandfather!), it can be quite philosophical at times.

The book is incredibly easy to read and very enjoyable. It's full of little facts and turns of phrase that you can share with others. And with its slightly philosophical angle, it might even get you thinking about how you spend your time. ★★★★★

***Chris North** is Ogden Science Lecturer and STFC Public Engagement Fellow at Cardiff University*

Northern Lights

Tom Kerss
Royal Observatory Greenwich
£8.99 ● PB



An awful lot of people get the Northern Lights wrong and return home from the Arctic Circle disappointed and feeling conned. Host of the excellent Star Signs weekly stargazing podcast and founder of Stargazing•London, Kerss has here produced a wonderfully comprehensive and well-written guide about all facets of Northern Lights-hunting. It sets expectations and arms the reader with exactly what they need to know, and much more besides.

As evidenced by the inclusion of many of his own photos, Kerss has spent a lot of time in the Arctic Circle. Indeed, the section on how to photograph the Northern Lights is very impressive, with lengthy advice on how to take images, but also how to post-process the results when you get home. There's even tips on using the latest smartphone cameras.

Clearly a student of the history of astronomy, Kerss also provides an entertaining overview of how our understanding of the aurora has changed over the centuries. Within these sections there are some surprising facts. For example, did you know the term aurora borealis was coined by Galileo in 1616? Or that Captain Cook witnessed the aurora over nine consecutive nights in 1770 while sailing south of the equator?

Along the way Kerss explains everything from our planet's magnetosphere to space weather, but crucially in language that's always straightforward. That's no mean feat when it comes to solar physics.

As Kerss states, you'll need perseverance and patience to see and photograph the Northern Lights. You won't need either to find enjoyment from this excellent guide to a fabulous natural phenomenon. ★★★★★

***Jamie Carter** is the author of* A Stargazing Program For Beginners: A Pocket Field Guide (Springer, 2015)

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1

2

3

4

5

6

1 Scopetech Mount Zero

Price £379 • **Supplier** First Light Optics
www.firstlightoptics.com

This single-arm fork mount can hold up to 7kg. The system, which uses worm gears and ball bearings, means that once you've set the friction you won't need to tighten or loosen it again.

2 Altair 2-inch dual-band 7nm CMOS nebula filter

Price £235 • **Supplier** Altair Astro
Tel 01263 731505 • **www.altairastro.com**

Bring out the details of nebulae with this dual band filter. It removes the need to swap between individual filters by transmitting light from both the Ha (hydrogen-alpha) and OIII (oxygen) wavelengths in your target, while suppressing unwanted wavelengths.

3 Plush astronaut penguin

Price £15 • **Supplier** Science Museum
http://shop.sciencemuseum.org.uk

Penguins might not be able to fly, but this feathered spacefarer can still shoot for the stars. A great gift for the little astronaut (or penguin enthusiast) in your life.

4 ASKAR F135 f/4.5 astrograph telephoto lens

Price £289 • **Supplier** 365 Astronomy
Tel 020 3384 5187 • **www.365astronomy.com**

At just 280g, this f/4.5 astrograph is a great basis for a lightweight astrophotography setup, whether you're using it with a DSLR camera, a specialist astronomy camera or as a guiding system. The triplet lens is made of high-quality glass with an in-built flattener. Fits 1.25-inch filters.

5 Ear warmer fleece cap

Price £12.99 • **Supplier** Coopers of Stortford
www.coopersofstortford.co.uk

Stay warm through the night with this cosy fleece cap. The stiff peak front will help protect your face from the wind, while the long earflaps will keep in the heat and stop your ears from getting cold.

6 Bresser 2-inch to 1.25-inch eyepiece adaptor

Price £35 • **Supplier** Telescope House
Tel 01342 837098 • **www.telescopehouse.com**

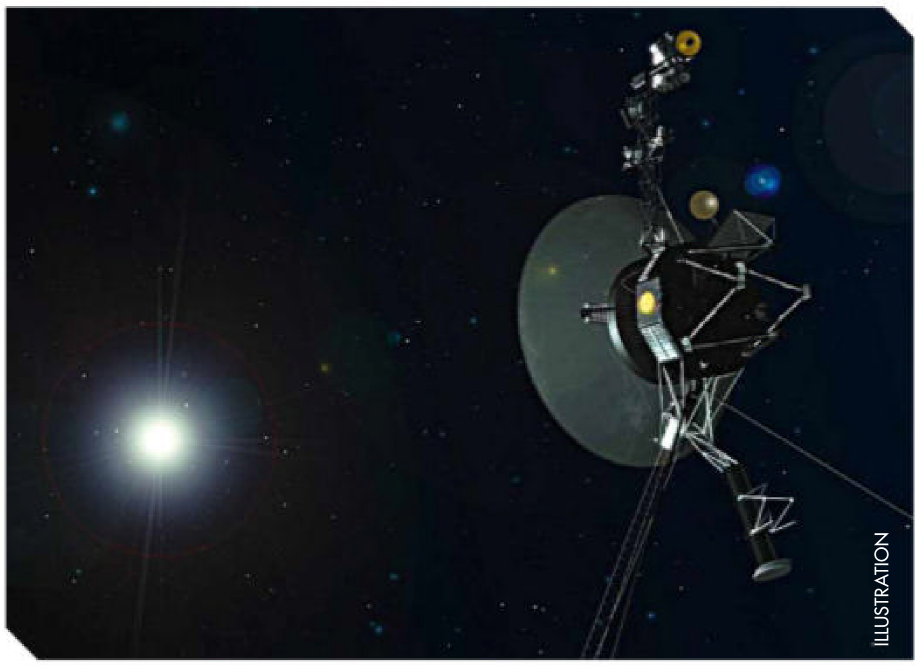
Increase the possibilities with your setup with this adaptor that allows you to use your 1.25-inch accessories in a larger 2-inch barrel. The adaptor's length is 34mm and the collar diameter is 60mm.

Shaoni Bhattacharya interviews Professor James Cordes

Q&A WITH A GRAVITATIONAL WAVE ASTRONOMER

Voyager 1's discovery of a 'plasma hum' outside our Solar System may be critical for finding future gravitational waves

What is Voyager 1 doing now?
It's over 40 years since the Voyager 1 and 2 spacecraft were launched in the late 1970s. They have now left the sphere of the Sun's influence – the heliosphere – and they are both sampling the conditions in the interstellar medium. This connects up with what I do, using ground-based radio telescopes to also study the interstellar medium.



▲ **Voyager 1's exploration of the interstellar medium is helping scientists to gather data about turbulence and its effect on gravitational wave detection**

How did you use data from Voyager 1 in your recent study in *Nature Astronomy*?
We analysed the signal from Voyager 1's Plasma Wave System (PWS), which uses antennae that hang off the spacecraft and measures low frequency radio waves. We look for oscillations that are at a frequency which characterises the density of the ionised gas (plasma) in the insterstellar medium

What did you find?
We learned that the plasma density changes as Voyager 1 moves along, and some of that change is due to turbulence in the interstellar gas. It's thin gas, less than one particle per cubic centimetre – but it's important on an astronomical scale. Other people had used this instrument to see specific events caused by big flares called coronal mass ejections. We were asking: is there a more continuous signal? We came up with a way of pulling that signal out of the noise in the data and that's how we identified the 'hum'.

What do you think is happening in the interstellar medium to cause this 'hum'?
It is electromagnetic waves coming from the oscillation of the plasma, in particular ionised hydrogen – protons and electrons unbound from each other. The electrons are oscillating back and forth past the heavier protons. The question is, what excites this? With the big events we've previously seen, the trigger is a coronal mass ejection. For this signal, though, the cause is not really understood. It could be some residual effects from coronal mass ejections, or it might just be a property of having hot gas that's moving, or it might be extremely energetic particles from cosmic rays. Whatever the mechanism, it's not a single event – it's something fairly persistent.

NASA/JPL-CALTECH

James Cordes is the George Feldstein Professor of Astronomy at Cornell University and a co-principal investigator of NANOGrav (the North American Nanohertz Observatory for Gravitational Waves).

Could we listen to the 'plasma hum'?
No, it's not really sound, it's a radio signal that's been measured. However, it's at the same frequency that we can hear, so you can translate the electromagnetic signal into sound the way a radio does.

What are the implications of your findings?
There are several implications. One is on the role of turbulence in the interstellar gas. New stars are forming out of gas clouds and there's turbulence there as well. So there are these deep physical connections between the very thin gas and dense gas that ultimately forms planets and stars.

The other is cosmic rays: they are energetic particles, so how do they get that energy? The understanding is that shock fronts accelerate those particles; but they don't move in a straight line, they make a random 'drunkard's walk' because of turbulence in the interstellar medium. Voyager 1 may tell us about what that looks like on a smaller scale.

The last connection is more astronomical. We know about twinkling stars, their light varies due to turbulence in Earth's atmosphere. We see a similar effect on radio waves viewed through interstellar turbulence; it can limit our precision in measurements.

Why does interstellar turbulence matter?
The NANOGrav project we are involved with at Cornell University uses pulsars as gravitational wave detectors. LIGO (the Laser Interferometer Gravitational-Wave Observatory) measures the gravitational waves to look at neutron stars using a ground-based detector that's a set of lasers. Instead we're using radio telescopes to look for gravitational waves from bigger black holes. These produce waves with long wavelengths, like a lightyear, so when they propagate through the Solar System it causes space-time to contract, or stretch. That's what we are trying to measure. It's a tiny, tiny effect so we have to worry about this interstellar medium stuff to make precise measurements. Gravitational wave detection is the biggest driver for us understanding all this.

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Email: sales@telescopehouse.com
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Introducing the Explore Scientifc Two-Room Pop-UP Observatory Tent / Weather protection for telescopes- £233
Explore Scientific iEXOS-100 Wifi Mount £389
PMC EIGHT
PRECISION MOTION CONTROLLER
Check out the Explore Scientific Deep Sky Cameras - all simple to use One Shot Colour systems featuring 1.7, 7.1 & 16 Megapixel Sensors. These cameras all feature set-point cooling and come with control software and heavy duty storage & carry cases.
16MP - £969
1.7MP - £1436
7.1MP - £2400
Explore Scientifc 99% Reflectivity Diagonal - £155
Explore Scientifc 127mm Apo - FROM £1429
NEW!
Introducing the new Explore Scientifc 70, 82, 100 and 120mm Astrobinoculars + U-Mount. Exceptional quality & value for money. Starting from £989
The Explore Scientifc 52-Degree Eyepiece Waterproof LER range from £67
Get organised with the Explore Scientifc Eyepiece & Accessory Bag- £28
National Geographic 114/500 Tabletop Dob - £129
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Check out the new Lunt LS40 starter Hydrogen Alpha Solarscope - £866.80
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ZWO ASIAIR Pro Wireless Scope control, Autoguiding & more.
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All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

The gas and ice giants put on a display this month, while Pegasus is perfectly placed for exploring

When to use this chart

1 Oct at 00:00 AEST (14:00 UT)
15 Oct at 23:00 AEDT (12:00 UT)
30 Oct at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

OCTOBER HIGHLIGHTS

The Moon has conjunctions with three planets in the western evening sky this month. On 9 October at the end of twilight, the three-day old crescent Moon is 7° below Venus. The following night these same objects form a triangle with the bright star Antares (Alpha (α) Scorpii). On 12 October, the Moon sits on Sagittarius's Teapot asterism. Two days later, the now gibbous Moon is 4° to the upper right of Saturn. The next day, it's a similar distance and position from Jupiter.

STARS AND CONSTELLATIONS

The northern sky is home to four mag. +2.0 stars that form the Great Square of Pegasus. Today, the constellation boundaries have the northeastern star in Andromeda, marking the head of the chained princess. Now known as Alpha (α) Andromedae, the star's origin is revealed by its Arabic name, Alpheratz – 'the horse's shoulder'. It also explains why Pegasus no longer has a 'delta' star, with Alpha (α), Beta (β) and Gamma (γ) Pegasi, forming the 'square'.

THE PLANETS

Venus is well placed in the western early evening sky, reaching its highest point at the end of the month. As dusk ends, Saturn and Jupiter are high in the north. In late October Saturn reaches its eastern quadrature, when you'll see the planet's shadow cast on its rings. October is also great for seeing the ice giants – Neptune transits the meridian (due north) mid-evening, shortly before Uranus.

DEEP-SKY OBJECTS

The southwestern (top left) star of the Great Square of Pegasus is Markab (Alpha (α) Pegasi), the gateway to the mag. +10.9 galaxy NGC 7479 (RA 23h 04.9m, dec. +12° 19'). Located 3° south of the star, this face-on spiral has a distinctive bar with a bright nucleus. Its halo extends from the bar's ends. With sufficient aperture (25cm), averted vision reveals two arms. The southern end is the most prominent, curving westwards.

Continue southwards through Pegasus another 3.5° and you'll find an obvious trapezium made up of four mag. +5.0 stars that fit within a 1.5° circle – ideal for observing with binoculars. Two stars are blue-white in colour, while the others are orange. One member is the double star 57 Pegasi (RA 23h 09.5m, dec. +8° 41'). This pair is mag. +5.0 and mag. +9.6, coloured yellowish orange and blue respectively, about 32.5 arcseconds apart.

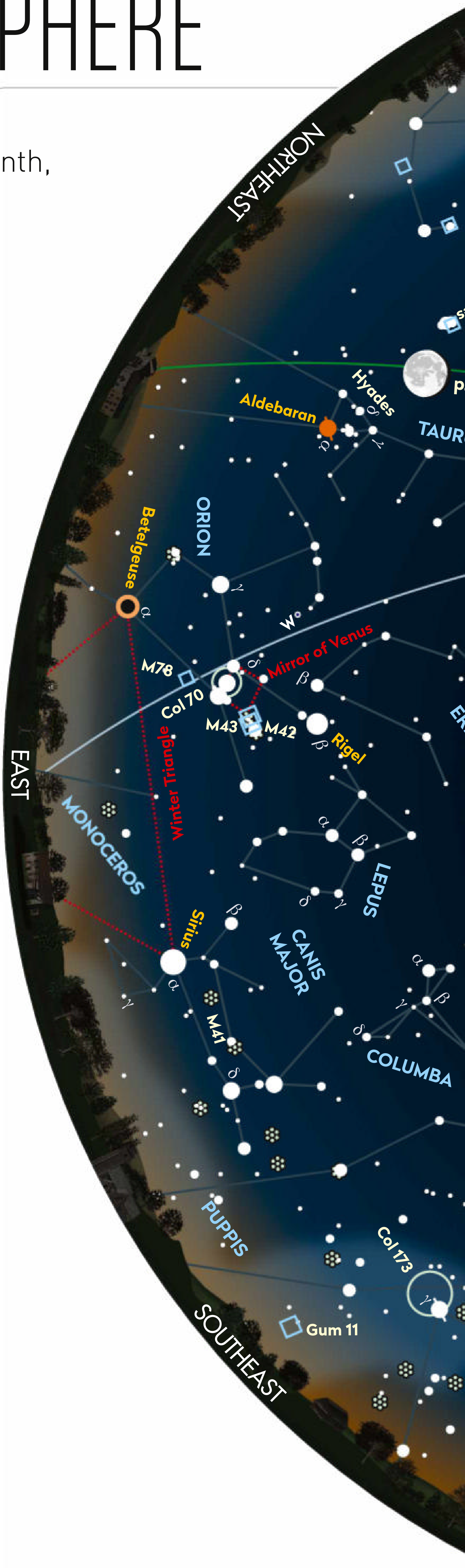

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
PERSEUS
Algol
M34
ANDROMEDA
M31
M110
M32
NGC 7686
LACERTA
Blue Snowball
CYGNUS
TRIANGULUM
NGC 752
M33
Alpheratz
PEGASUS
Great Square of Pegasus
Markab
Veil Nebula
Summer Triangle
Dumbbell
ARIES
Ecliptic
Uranus
PISCES
NGC 7479
Circlet
DELPHINUS
SAGITTA
Menkar
20th
Water Jar
Enif
M15
EQUULEUS
Altair
AQUILA
Celestial Equator
CETUS
Neptune
17th
M2
AQUARIUS
SERPENS CAUDA
Deneb Kaitos
NGC 253
Jupiter
Saturn Nebula
FORNAX
Fomalhaut
Helix Nebula
CAPRICORNUS
SCULPTOR
PISCIS AUSTRINUS
14th
Saturn
PHOENIX
GRUS
MICROSCOPIUM
Pluto
SAGITTARIUS
SCUTUM
M11
HOROLOGIUM
CAELUM
INDUS
M55
M25
M16
M17
DORADO
RETICULUM
Achernar
TUCANA
47 Tucanae
Teapot
M22
M28
M21
M20
M23
M8
11th
SMC
HYDRUS
Tarantula Nebula
PICTOR
LMC
MENSA
OCTANS
CORONA AUSTRALIS
TELESCOPIUM
M7
M6
Gum 67
Canopus
VOLANS
PAVO
South Celestial Pole
APUS
ARA
SCORPIUS
CHAMAELEON
NGC 2808
CARINA
MUSCA
NGC 4833
TRIANGULUM AUSTRALE
NORMA
CIRCINUS
Southern Pleiades
h Carina Nebula
Rigel Kent
CENTAURUS
Acrux
Coal Sack
CRUX
Jewel Box
VELA

Sky-Watcher®
Be amazed.
ED APOCHROMATIC REFRACTORS
ED OPTICS
Sky at Night MAGAZINE REVIEWED IN Issue 161 October 2018
OTA reviewed
EVOSTAR™ DS-PRO ED APO DOUBLETS
EVOSTAR-72ED DS-PRO
72mm f/ 5.8 OTA
Code: 10201
SRP £349
Sky at Night MAGAZINE REVIEWED IN Issue 158 JULY 2018
EVOSTAR-80ED DS-PRO
80mm f/7.5 OTA
Code: 10202
SRP £629
"Great all-round package…Overall this telescope packs a lot of punch…a complete setup with lovely crisp optics"
BBC SKY AT NIGHT MAGAZINE
SRP £1869
SRP of OTA only
EVOSTAR-150ED DS-PRO
150mm f/8 OTA
Code: 10198
SYNSCAN™ GO-TO
SRP £1499
EQ6-R PRO SYNSCAN MOUNT
SRP of Mount only
Code 20855
EVOSTAR-100ED DS-PRO
100mm f/9 OTA
Code: 10203
SRP £999
Sky at Night MAGAZINE GROUP TEST WINNER
Awarded to Evostar-100ED (previous single-speed version) Group test: 4-inch Apochromatic Refractors under £3000
EVOSTAR-120ED DS-PRO
120mm f/7.5 OTA
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SRP £1469
0.85x FOCAL REDUCERS/CORRECTORS FOR EVOSTAR ED DS-PRO
Require M48x0.75 DSLR Adaptor – Canon and Nikon Adaptors available at £19.99 SRP
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For Evostar-80ED Code 20236
For Evostar-100ED Code 20235
For Evostar-120ED Code 20234
For Evostar-150ED Code 20321
SRP £219
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ESPRIT-80ED
80mm f/5 OTA
Code: 10243
SRP £1249
SRP £2599
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Require M48x0.75 DSLR Adaptor – Canon & Nikon Adaptors available at £19.99 SRP
For Esprit-80ED Code: 20187 SRP £149
For Esprit-100ED Code: 20188 SRP £199
For Esprit-120ED Code: 20189 SRP £249
For Esprit-150ED Code: 20190 SRP £299
"In short, the Esprit provided first-class optical performance visually and photographically…The Esprit-120's performance matches the best in the business at a competitive price"
SKYNEWS MAGAZINE REVIEW BY ALAN DYER
ESPRIT-120ED
120mm f/7 OTA Code: 10233
ESPRIT-100ED
100mm f/5 OTA Code: 10244
Sky at Night MAGAZINE REVIEWED IN Issue 109 June 2014
ESPRIT-150ED
150mm f/7 OTA
Code: 10234
"Star images were excellent across the full width of the sensor…The optics feature a high level of correction across the field and star images through all filters were tight and consistent thanks to its superb colour correction."
ASTRONOMY NOW MAGAZINE REVIEW BY NIK SZYMANEK
SRP £4999
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